US011384759B2

(12) **United States Patent**
Bhatia et al.

(10) **Patent No.: US 11,384,759 B2**
(45) **Date of Patent: Jul. 12, 2022**

(54) VAPOR INJECTION DOUBLE REED VALVE PLATE

(71) Applicant: **Hanon Systems**, Daejeon (KR)

(72) Inventors: **Kanwal Bhatia**, Canton, MI (US); **Rod Callahan**, Novi, MI (US); **Kyung Jae Lee**, Daejeon (KR); **Steven J. Koester**, Toledo, OH (US); **Jeong Ki Seo**, Daejeon (KR)

(73) Assignee: **HANON SYSTEMS**, Daejeon (KR)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 2 days.

(21) Appl. No.: **17/101,756**

(22) Filed: **Nov. 23, 2020**

(65) **Prior Publication Data**

US 2021/0285445 A1 Sep. 16, 2021

Related U.S. Application Data

(60) Provisional application No. 62/987,638, filed on Mar. 10, 2020.

(51) **Int. Cl.**
F04C 18/02 (2006.01)
F04C 29/04 (2006.01)
(Continued)

(52) **U.S. Cl.**
CPC ***F04C 18/0215*** (2013.01); ***F04C 18/0261*** (2013.01); ***F04C 29/042*** (2013.01);
(Continued)

(58) **Field of Classification Search**
CPC F04C 18/0215–0292; F04C 29/0007; F04C 29/0014; F04C 29/042;
(Continued)

(56) **References Cited**

U.S. PATENT DOCUMENTS

2,064,754 A * 12/1936 Ivens F04B 39/1073 137/454.4
4,257,458 A * 3/1981 Kondo F16K 15/16 137/512.15

(Continued)

FOREIGN PATENT DOCUMENTS

EP 3572671 A1 * 11/2019 .... F04C 28/24
JP H11230063 A 8/1999

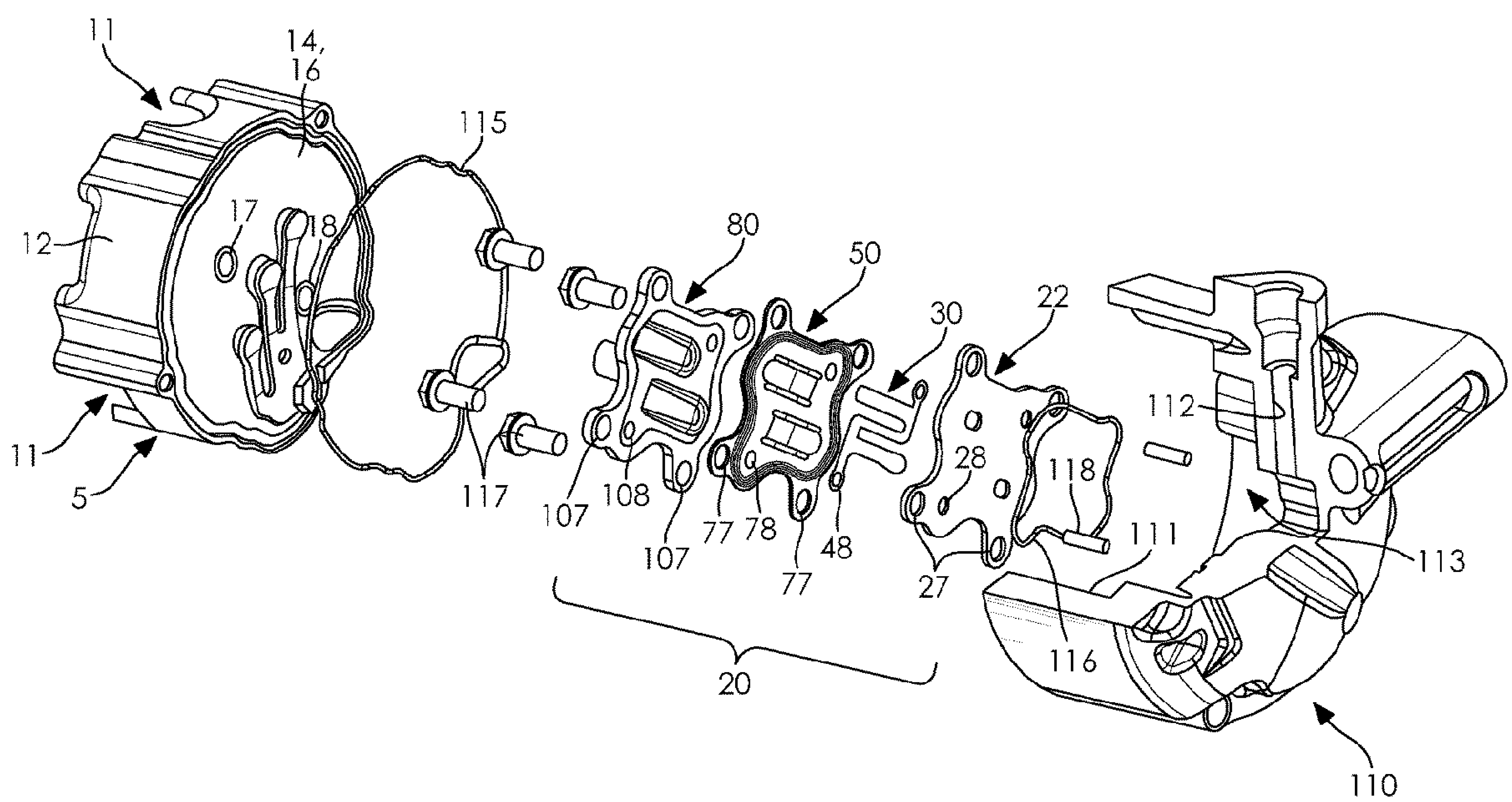
(Continued)

Primary Examiner — Mark A Laurenzi
Assistant Examiner — Xiaoting Hu
(74) *Attorney, Agent, or Firm* — Shumaker, Loop & Kendrick, LLP; James D. Miller

(57) **ABSTRACT**

A valve assembly forms a check valve for a scroll compressor including a fixed scroll having a pair of injection ports fluidly coupled to a compression mechanism. The valve assembly includes a valve body having a pair of flow paths with each of the flow paths fluidly coupled to a corresponding one of the injection ports. An injection plate has a pair of injection holes. A reed structure is disposed between the injection plate and the valve body with the reed structure including a pair of reeds. Each of the reeds is configured to selectively provide fluid communication between a corresponding one of the injection holes and a corresponding one of the injection ports. A valve gasket is disposed between the reed structure and the valve body and includes a pair of flaps with each of the flaps configured to selectively contact a corresponding one of the reeds.

19 Claims, 7 Drawing Sheets



(51) **Int. Cl.**
F04C 29/12 (2006.01)
F04C 28/26 (2006.01)

(52) **U.S. Cl.**
CPC *F04C 28/26* (2013.01); *F04C 29/128* (2013.01); *F04C 2210/26* (2013.01); *F04C 2240/30* (2013.01); *F04C 2270/58* (2013.01)

(58) **Field of Classification Search**
CPC .. F04C 29/126; F04C 29/128; F04C 2270/58; F04C 18/0261
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

5,073,146	A *	12/1991	Beck	F04B 39/1066 417/571
5,885,064	A *	3/1999	McCoy	F04B 39/1086 417/569
2017/0030471	A1	2/2017	Rosa	
2020/0063737	A1 *	2/2020	Nakai	F04C 29/0007

FOREIGN PATENT DOCUMENTS

JP	2015129475	A *	7/2015	F04C 28/24
JP	2015129475	A	7/2015	
JP	2018053827	A	4/2018	
WO	2018003525	A1	1/2018	

* cited by examiner

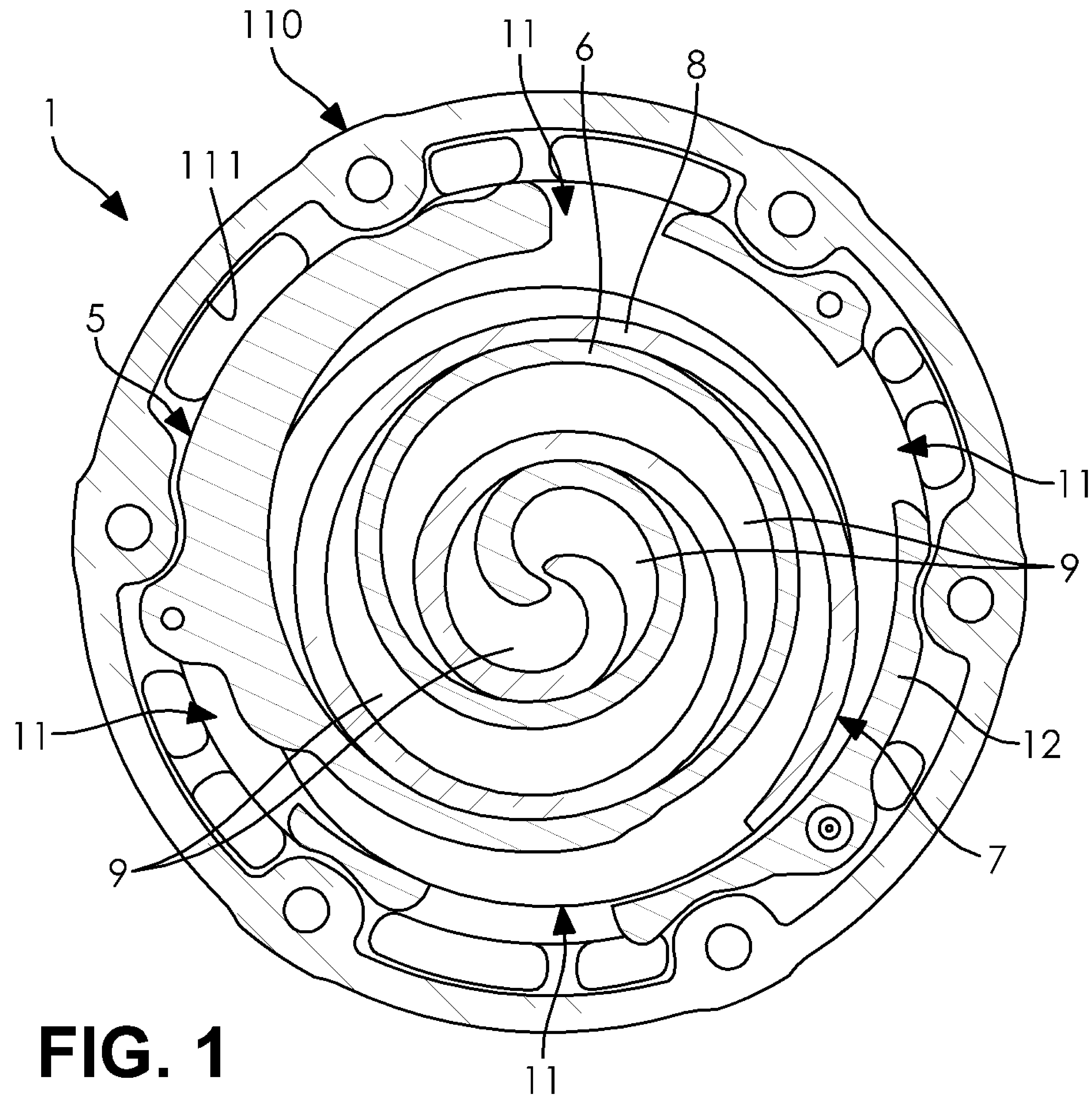


FIG. 1

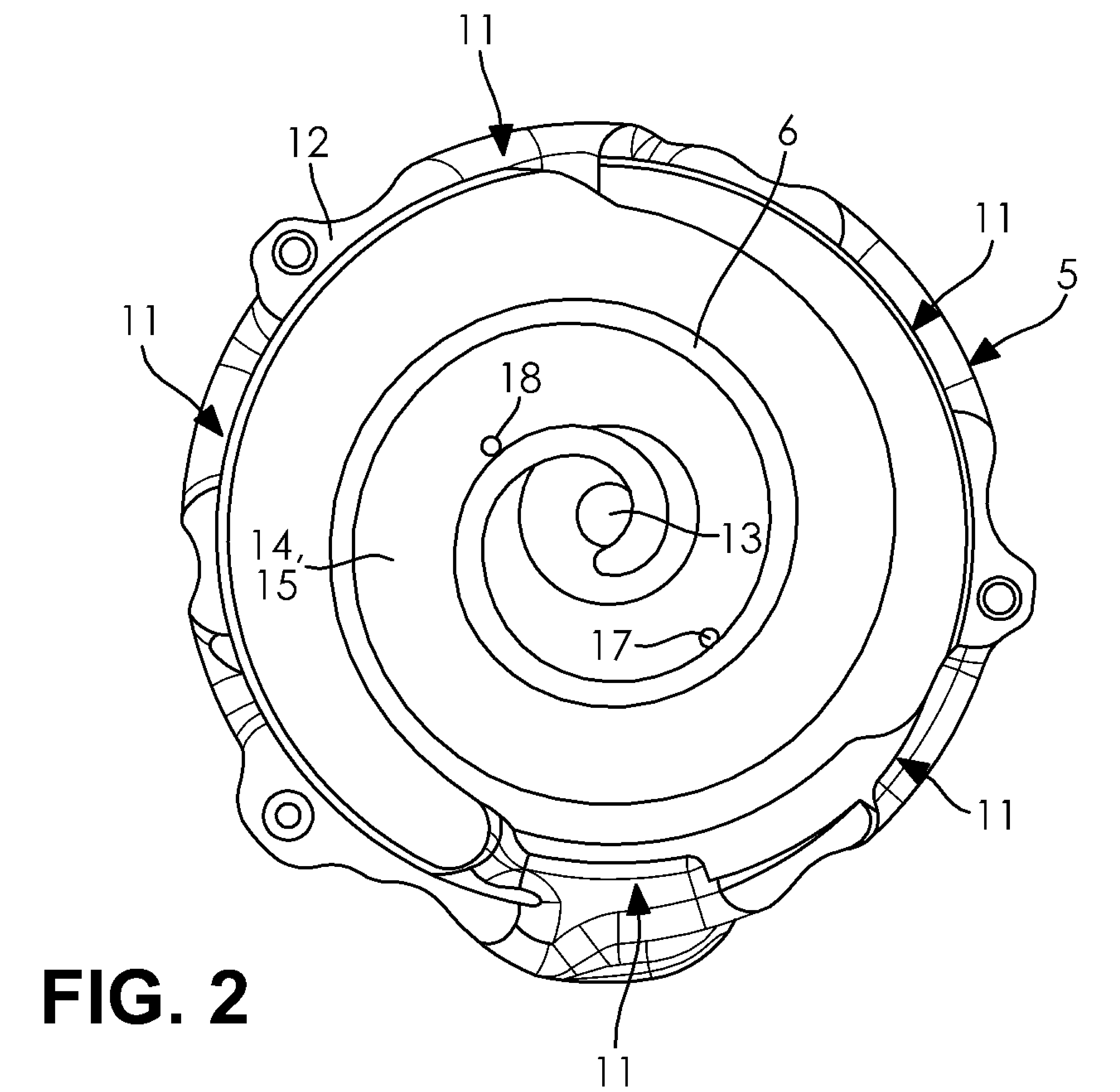


FIG. 2

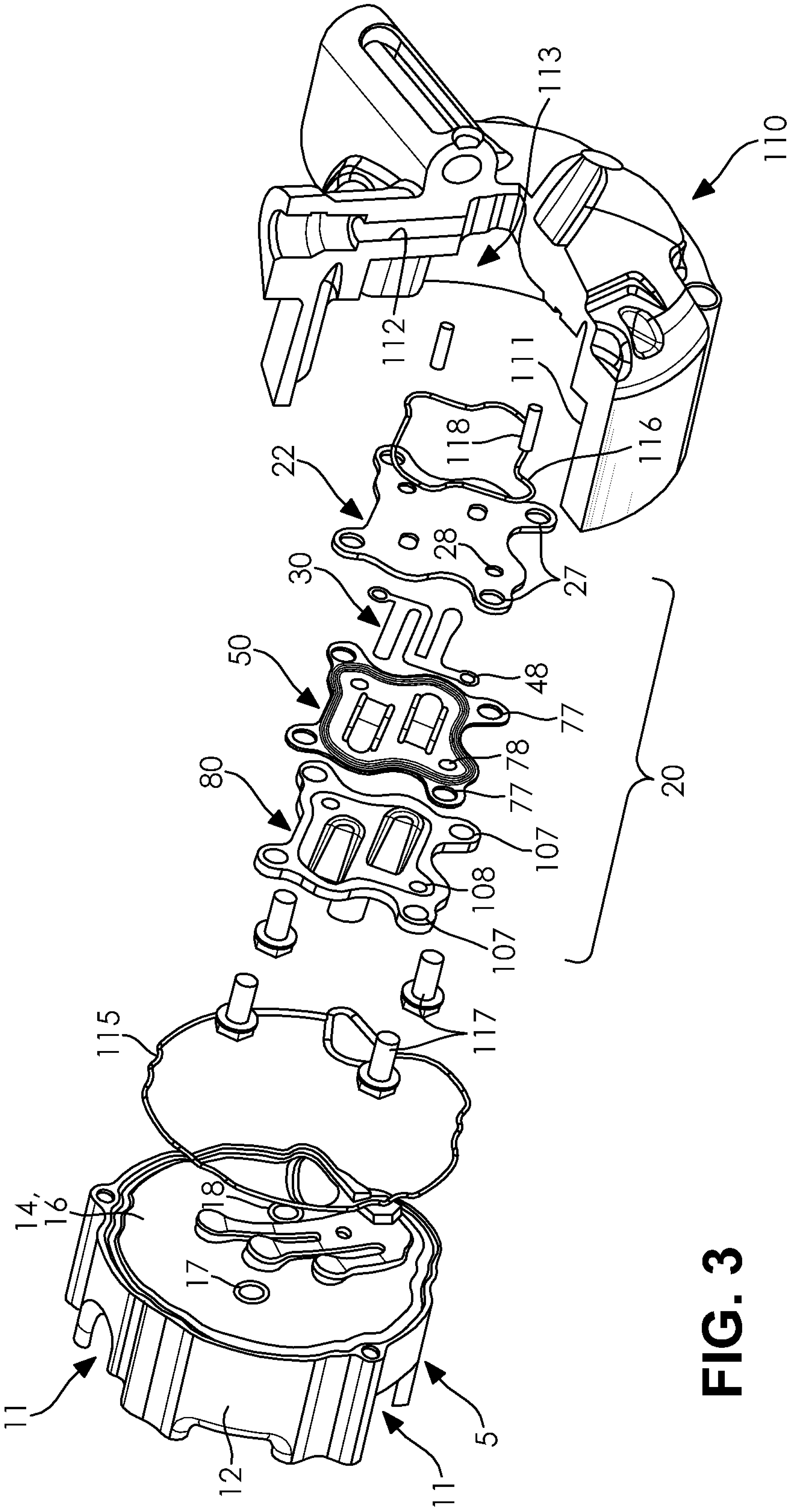

113
110
112
111
118
116
22
28
27
30
48
50
77
78
77
80
107
108
107
20
115
117
14,
16
18
17
11
12
11
5

FIG. 3

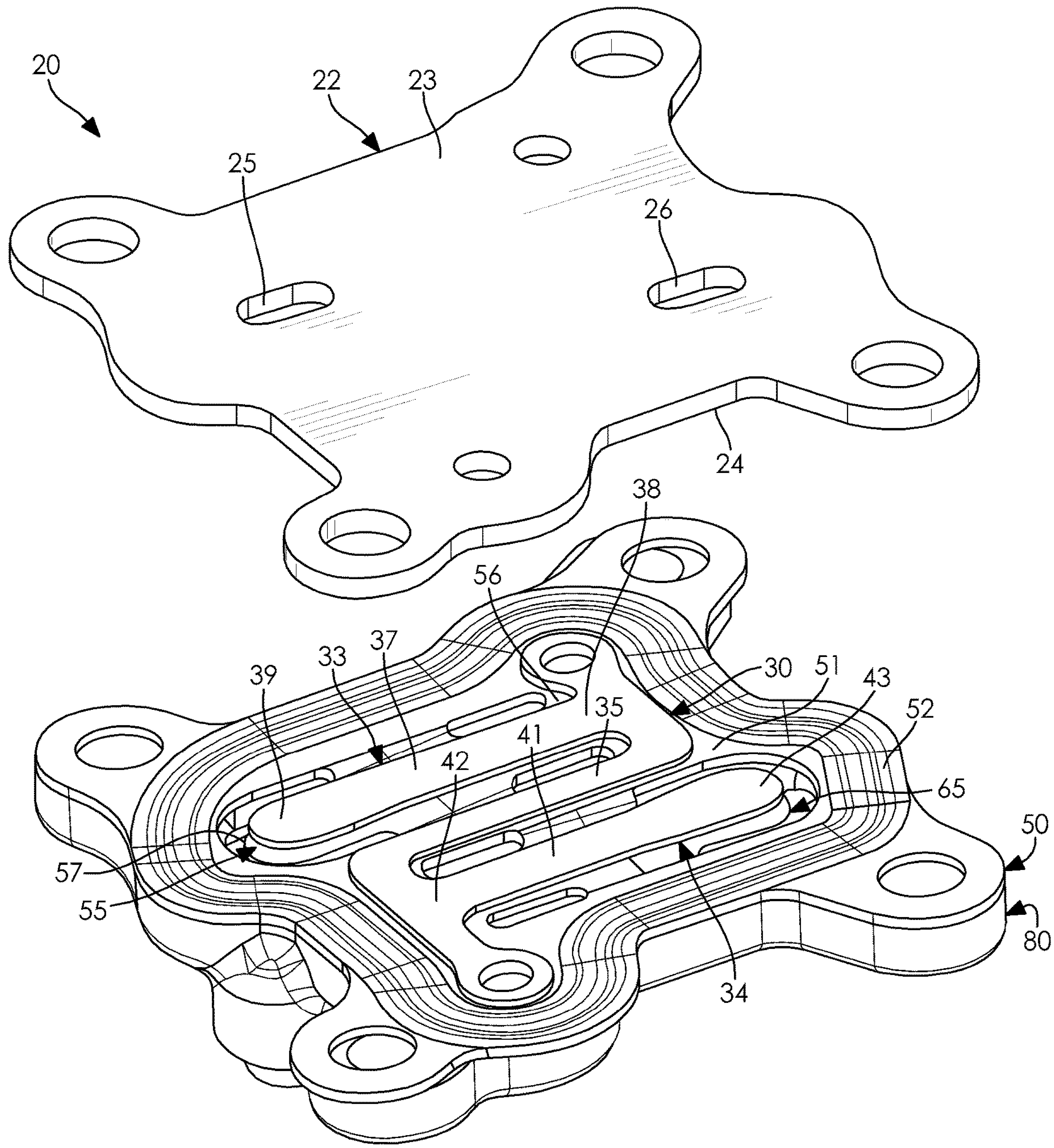
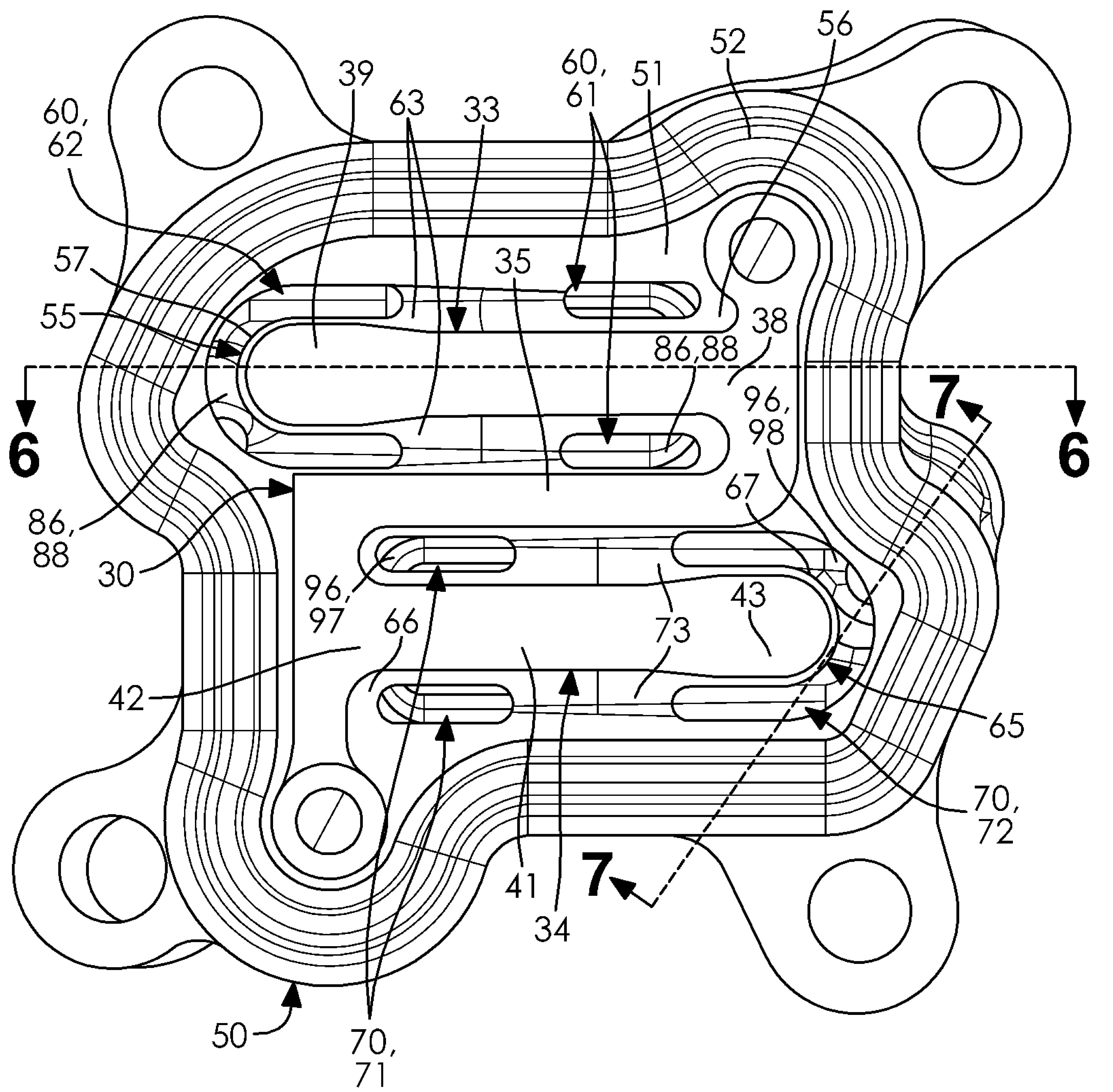


FIG. 4



39
63
33
60,
61
51
52
56
60,
62
57
55
35
38
86,88
96,
98
7
6
6
86,
88
30
67
96,
97
66
43
73
42
65
70,
72
41
34
7
50
70,
71

FIG. 5

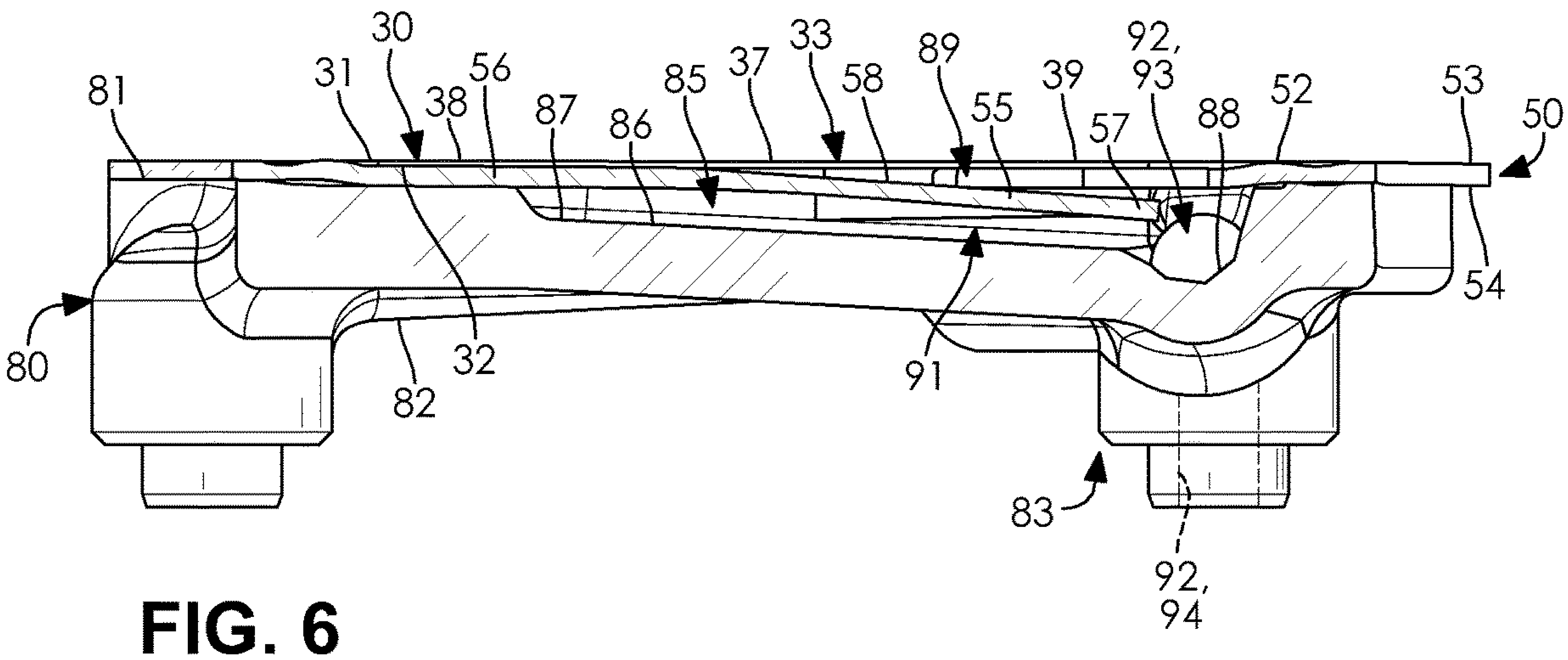

30
31
38
56
33
37
85
89
58
92,
93
39
55
57
88
52
53
50
81
87
86
80
32
82
91
54
83
92,
94

FIG. 6

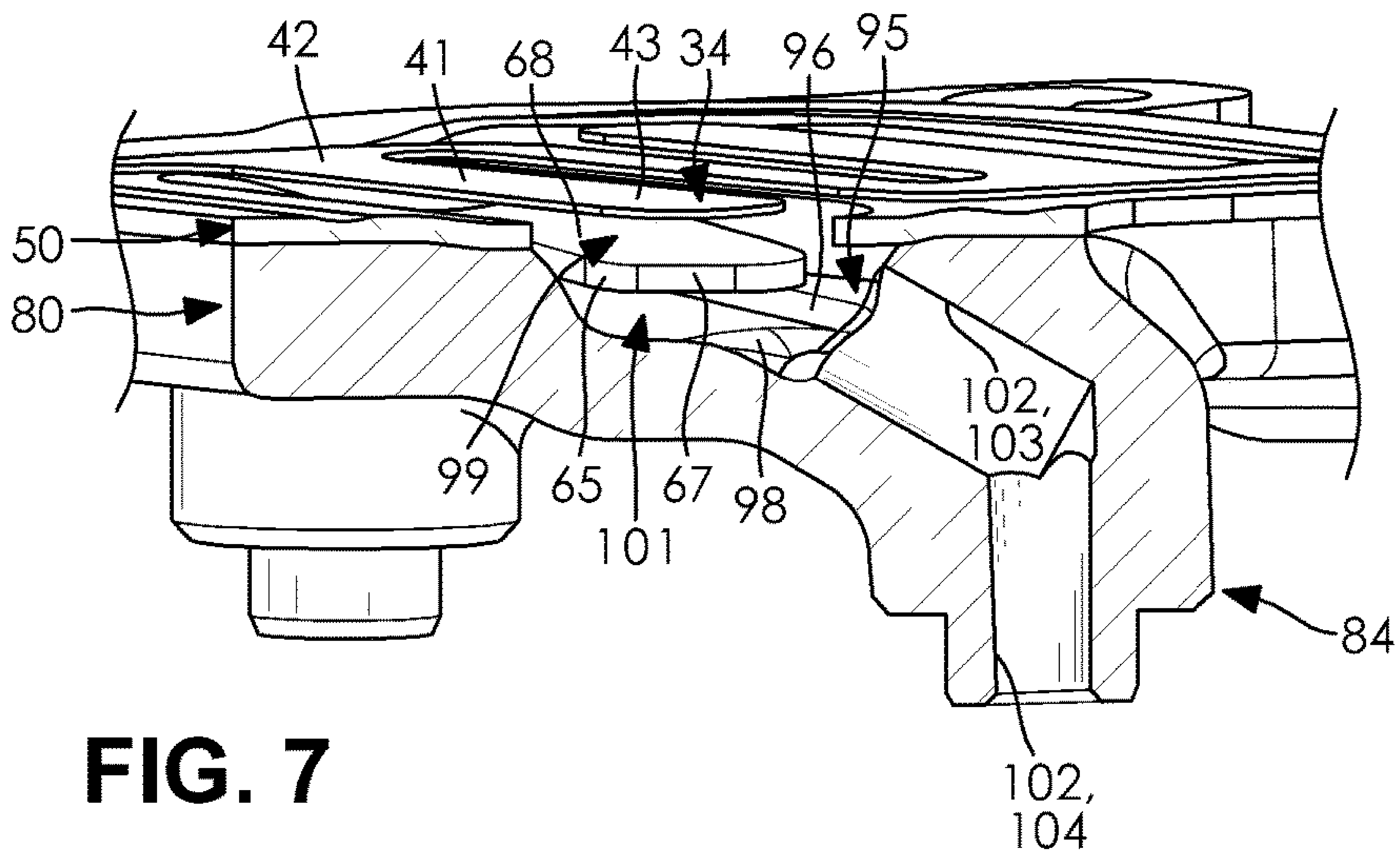

42
41
68
43
34
96
95
50
80
99
65
67
98
101
102,
103
84
102,
104

FIG. 7

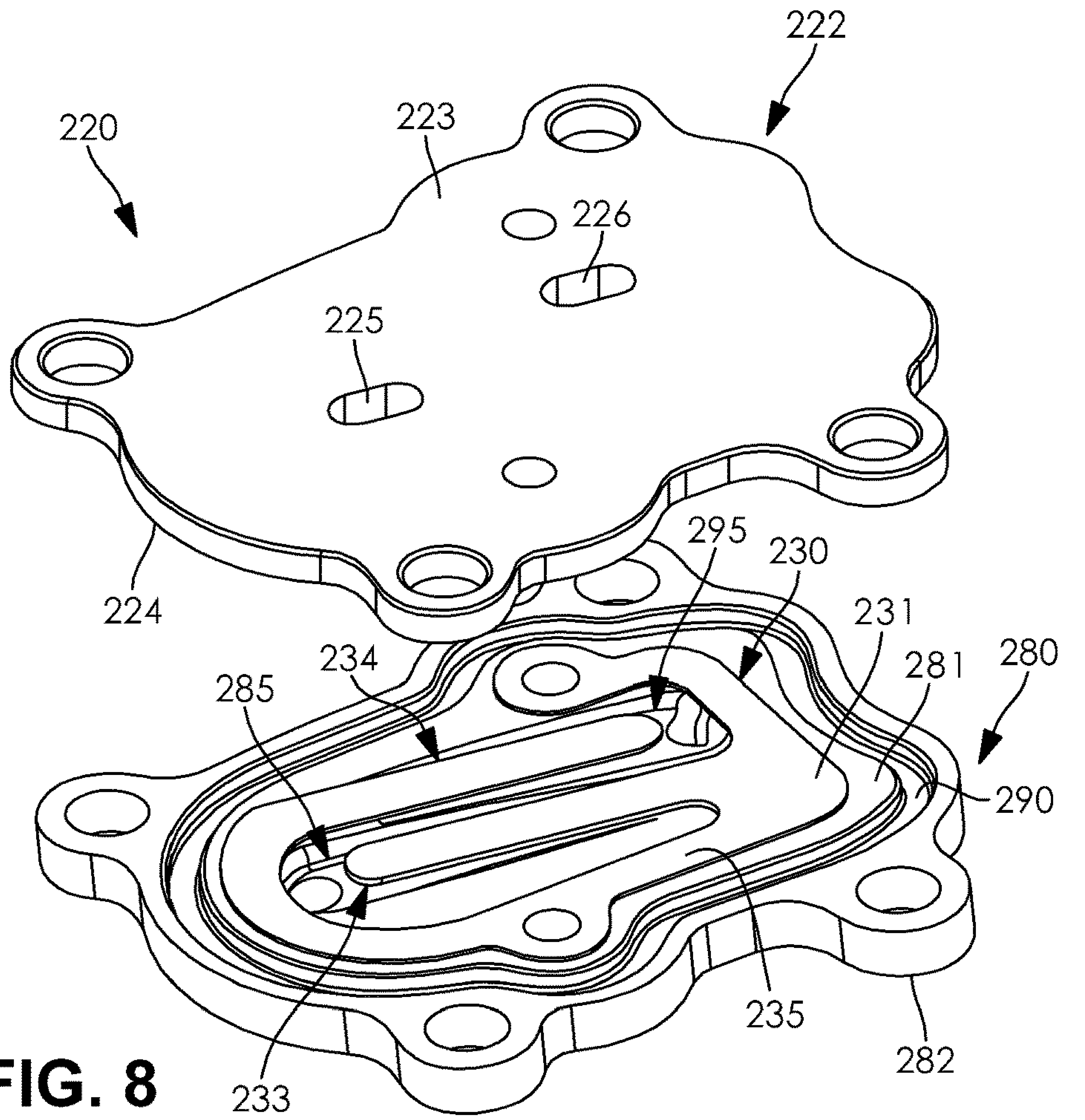

222
220
223
226
225
224
295
230
231
281
280
234
285
290
235
282
233

FIG. 8

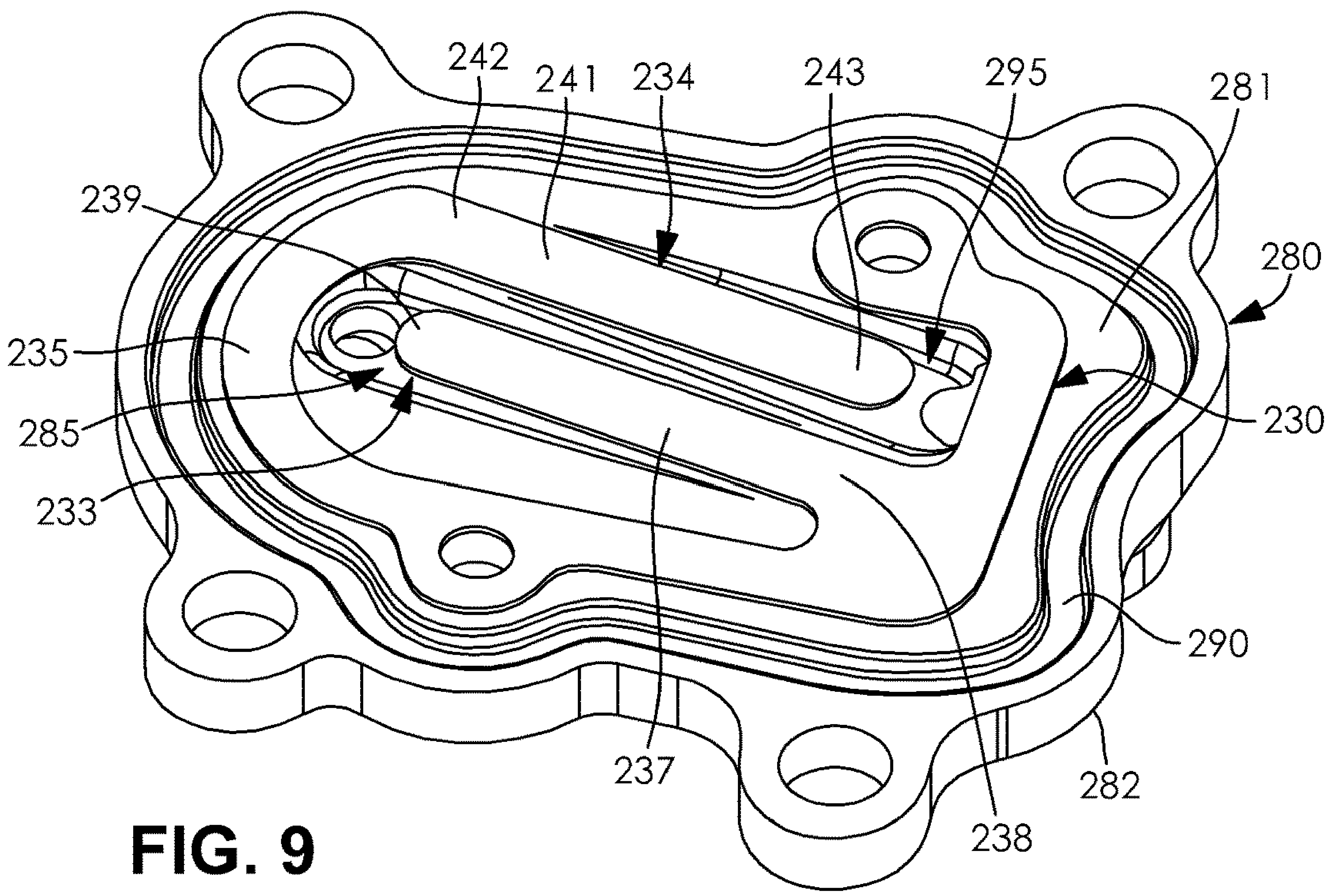

242
241
234
243
295
281
239
280
235
285
230
233
290
237
282
238

FIG. 9

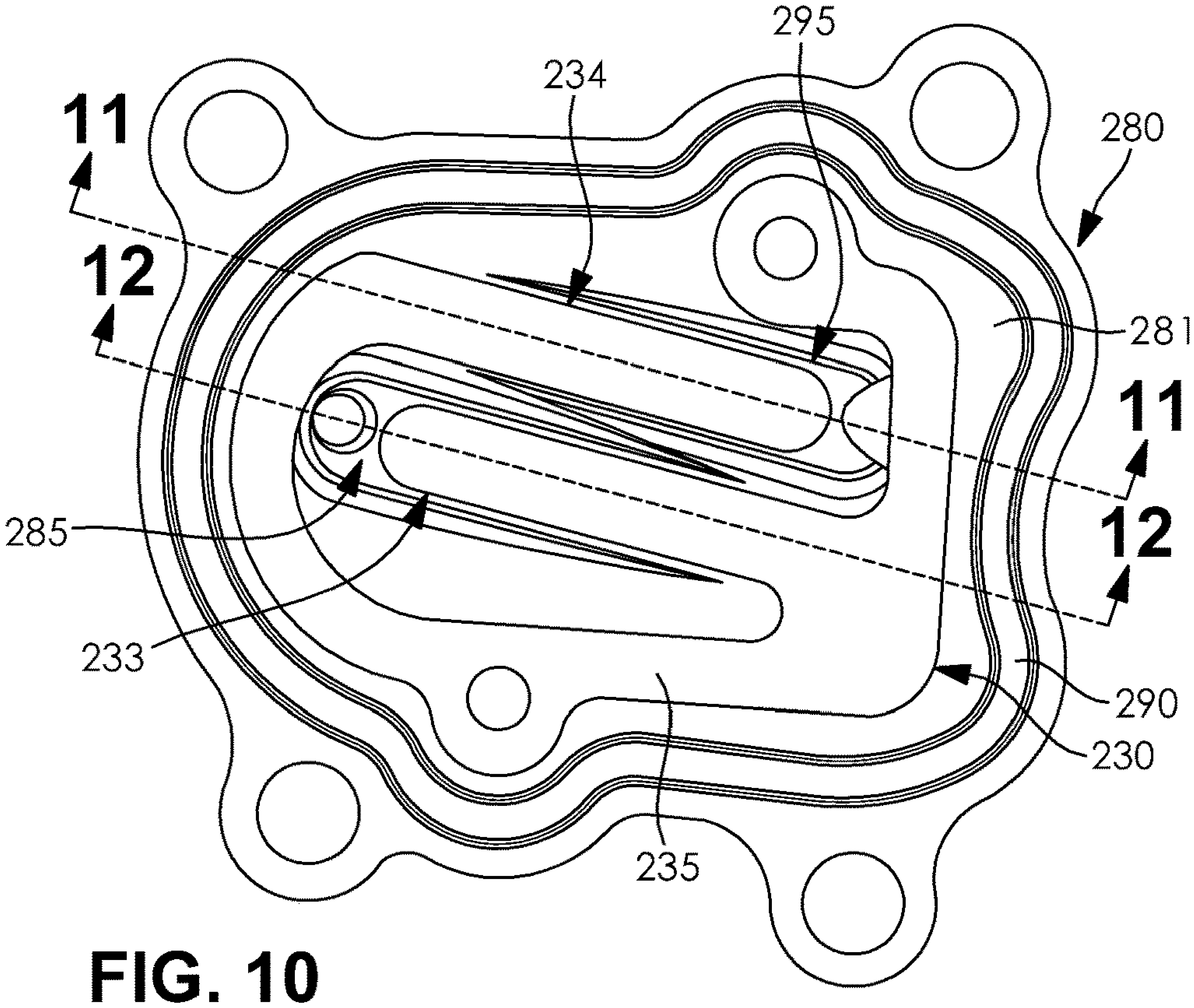


FIG. 10

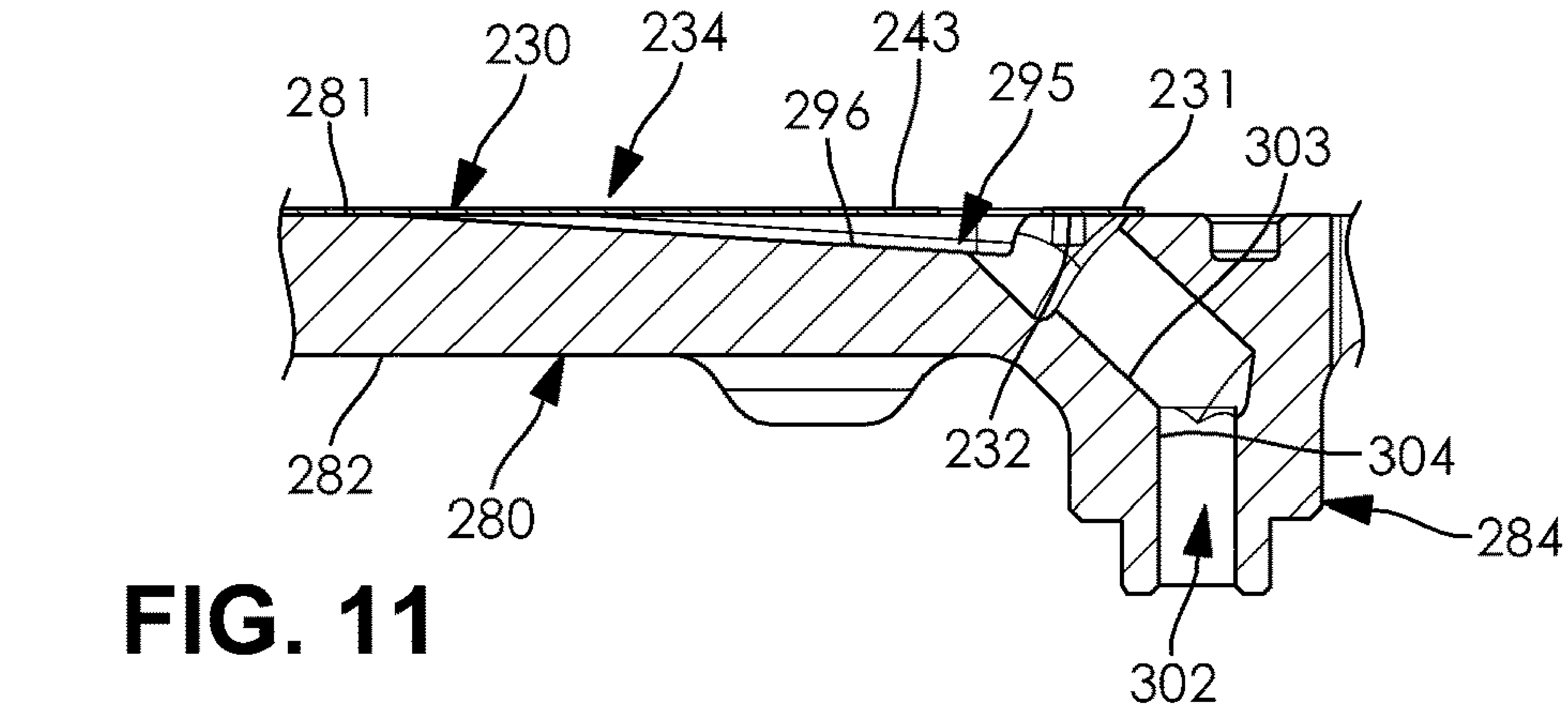


FIG. 11

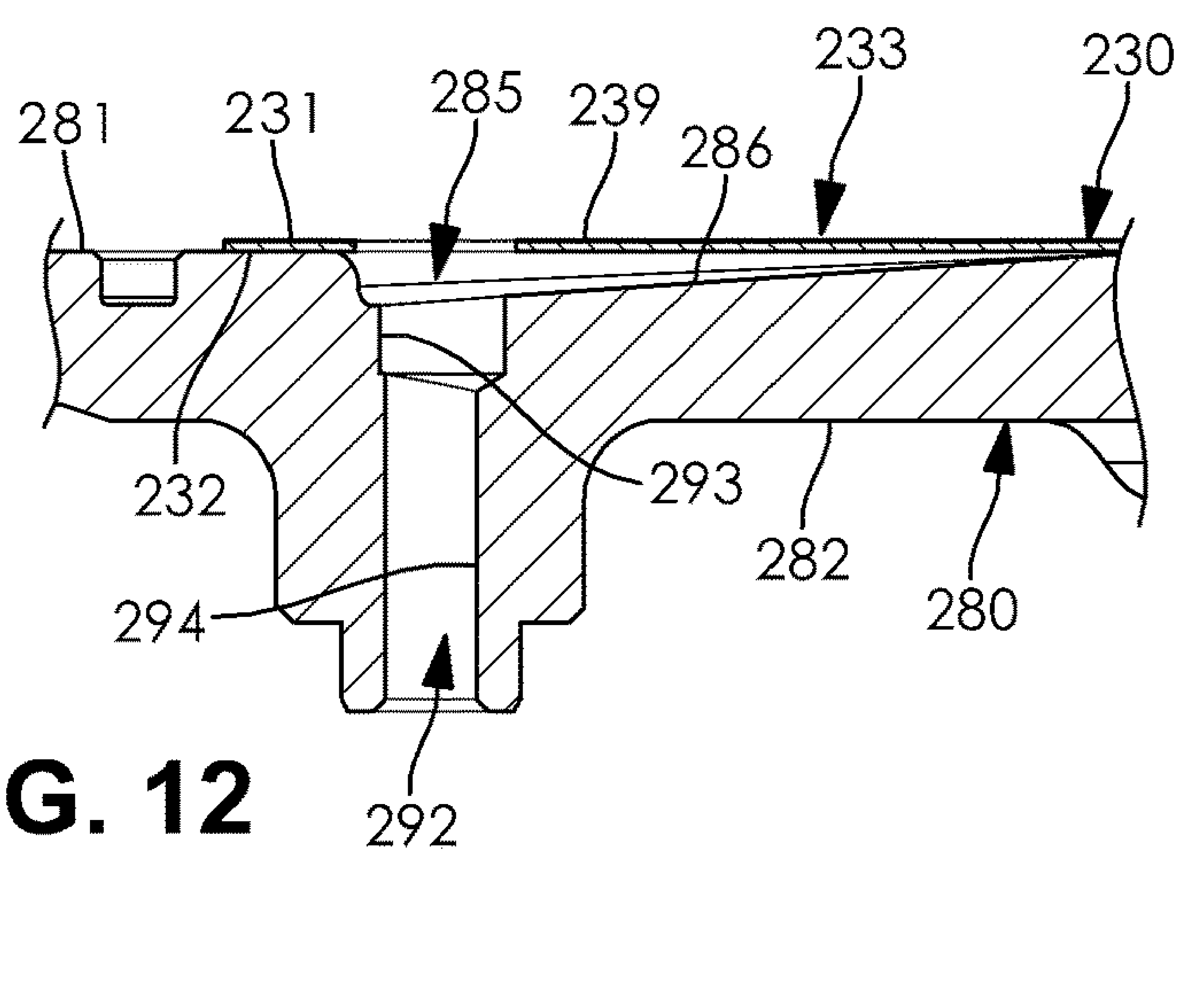


FIG. 12

VAPOR INJECTION DOUBLE REED VALVE PLATE

CROSS-REFERENCE TO RELATED APPLICATION

This patent application claims priority to U.S. Provisional Patent Application Ser. No. 62/987,638, filed on Mar. 10, 2020, the entire disclosure of which is hereby incorporated herein by reference.

FIELD OF THE INVENTION

The invention relates to a check valve assembly for preventing back flow and distributing fluid evenly to a scroll compressor with minimal flow losses.

BACKGROUND OF THE INVENTION

As is commonly known, vehicles typically include a heating, ventilating, and air conditioning (HVAC) system. In certain applications, a scroll compressor is employed for compressing a refrigerant circulated through a refrigerant circuit of the HVAC system. More specifically, such refrigerant circuits may be configured for use with a vapor injection scroll compressor that utilizes two different inputs of the refrigerant at different pressures and/or temperatures for optimizing the capacity of the vapor injection scroll compressor in comparison to single input scroll compressors. This is typically achieved by returning a portion of the refrigerant back towards the vapor injection scroll compressor after initially exiting the compression chambers of the vapor injection scroll compressor. Depending on the configuration of the refrigerant circuit, the returned refrigerant may be expanded via a corresponding expansion element, subcooled via a corresponding heat exchanger, or separated via a cyclone separator or the like, as well as any combinations thereof, prior to reentry back into the vapor injection scroll compressor to ensure that the returned refrigerant has the desired characteristics for the given application.

Generally, scroll compressors include a fixed scroll that remains stationary and an orbiting scroll that is nested relative to the fixed scroll and configured to orbit relative to the fixed scroll. The orbiting motion of the orbiting scroll, as well as the similar spiral shape of each of the fixed scroll and the orbiting scroll, continuously forms corresponding pairs of substantially symmetric compression chambers between the fixed scroll and the orbiting scroll. Each pair of the compression chambers is typically symmetric about a centralized discharge port of the vapor injection scroll compressor. Refrigerant typically enters each of the compression chambers via one or more inlet ports formed adjacent a radially outmost portion of the fixed scroll and then the orbiting motion of the orbiting scroll relative to the fixed scroll results in each of the compression chambers progressively decreasing in volume such that the refrigerant disposed within each of the compression chambers progressively increases in pressure as the refrigerant approaches the radially central discharge port.

The vapor injection scroll compressor is distinguished from traditional scroll compressors by injecting the returned refrigerant into each of the symmetrically formed compression chambers at a corresponding intermediate position disposed radially between the outwardly disposed inlet ports and the centrally disposed discharge port of the fixed scroll. Due to the presence of the pairs of the symmetric compression chambers between the cooperating scrolls, it is beneficial to introduce the returned refrigerant at two different injection openings that are similarly substantially symmetrically disposed relative to the centrally disposed discharge port such that each of the paired compression chambers receives a flow of the returned refrigerant at similar positions within the compression process. The injected refrigerant accordingly enters each of the compression chambers at a position corresponding to a region of the fixed scroll repeatedly subjected to a pressure of the radially inwardly flowing refrigerant that is generally intermediate the suction pressure formed at the inlet ports and the discharge pressure formed at the discharge port of the fixed scroll. The injected refrigerant originates from an injection chamber of the vapor injection scroll compressor configured to receive the returned refrigerant therein prior to reintroduction back into the compression chambers.

Additionally, the continuous orbiting of the orbiting scroll relative to the fixed scroll results in each of the injection openings formed in the fixed scroll being subjected to a variable pressure during each orbit of the orbiting scroll based on whether a corresponding portion of the orbiting scroll has passed by the corresponding injection opening with respect to each orbit cycle. It is therefore necessary for each of the injection openings of the fixed scroll to be associated with a corresponding check valve for ensuring that the returned refrigerant is injected into the corresponding compression chamber in a single flow direction. Specifically, the check valves ensure that the returned refrigerant can enter the corresponding compression chamber only when the refrigerant already disposed within the compression chamber is at a relatively low pressure that is lower than the pressure of the injected refrigerant. The check valve further prevents an occurrence wherein any compressed refrigerant at a relatively high pressure greater than that of the injected refrigerant flows in reverse (backflows) through the injection opening, through the injection chamber, and towards any components disposed upstream of the injection chamber with respect to the returned refrigerant, such as the aforementioned cyclone separator.

Such check valves may be provided as ball valves that are biased by a spring or the like to a closed position until the injected refrigerant pressure exceeds the pressure of the refrigerant present within the corresponding compression chamber. However, it has been discovered that the use of such ball valves may result in an undesirable pressure drop in the injected refrigerant that reduces the output capacity of the vapor injection scroll compressor. Other shortcomings of such ball valves may be the need for multiple components such that manufacturing complexity is increased, a need for increased axial packaging space for accommodating the motion of the ball relative to the spring, and an inconsistency of the distribution of the injected refrigerant to each of the pair of the injection openings.

Such a check valve may also be provided as a reed valve having a flexible metallic reed that flexes in response to a pressure differential thereacross. However, such reed valves are traditionally provided to include repeated metal to metal contact, which greatly reduces the durability of such reed valves and also introduces a concern of noise, vibration, and harshness (NVH) that can potentially be experienced by a passenger of a vehicle.

It would therefore be desirable to provide an improved and durable check valve mechanism to minimize back flow of the refrigerant, more evenly distribute the refrigerant between each of the injection openings when entering the corresponding compression chambers, and prevent an occurrence of NVH during operation thereof.

SUMMARY OF THE INVENTION

Consistent and consonant with the present invention, an improved check valve assembly for use with a vapor injection scroll compressor is disclosed.

According to an embodiment of the present invention, a valve assembly for a scroll compressor including a fixed scroll having a first injection port fluidly coupled to a compression mechanism of the scroll compressor is disclosed. The valve assembly includes a valve body having a first flow path formed therethrough with the first flow path fluidly coupled to the first injection port. An injection plate has a first injection hole formed therethrough. A reed structure is disposed between the injection plate and the valve body. The reed structure includes a first reed configured to selectively permit a fluid to flow through the first injection hole towards the first flow path for entry into the compression mechanism through the first injection port.

According to another embodiment of the present invention, a valve assembly forms a check valve for a scroll compressor including a fixed scroll having a pair of injection ports fluidly coupled to a compression mechanism of the scroll compressor. The valve assembly includes a valve body having a pair of flow paths formed therethrough with each of the flow paths fluidly coupled to a corresponding one of the injection ports. An injection plate has a pair of injection holes formed therethrough. A reed structure is disposed between the injection plate and the valve body with the reed structure including a pair of reeds. Each of the reeds is configured to selectively provide fluid communication between a corresponding one of the injection holes and a corresponding one of the injection ports. A valve gasket is disposed between the reed structure and the valve body and includes a pair of flaps with each of the flaps configured to selectively contact a corresponding one of the reeds.

According to yet another embodiment of the present invention, a vapor injection scroll compressor comprises a compression mechanism formed by the cooperation of a fixed scroll and an orbiting scroll. The compression mechanism is configured to compress a fluid therein. The fixed scroll includes a pair of injection ports formed therethrough with each of the injection ports in fluid communication with the compression mechanism. An injection chamber is configured to receive a portion of the fluid after being compressed within the compression mechanism. A valve assembly includes a reed structure having a pair of reeds. Each of the reeds is configured to selectively provide fluid communication between the injection chamber and a corresponding one of the injection ports.

BRIEF DESCRIPTION OF THE DRAWINGS

The above, as well as other objects and advantages of the invention, will become readily apparent to those skilled in the art from reading the following detailed description of an embodiment of the invention when considered in the light of the accompanying drawing which:

FIG. **1** is a cross-sectional elevational view taken through a compression mechanism of a scroll compressor according to an embodiment of the present invention;

FIG. **2** is an axial end elevational view of a fixed scroll of the compression mechanism of FIG. **1** with the fixed scroll shown in isolation;

FIG. **3** is an exploded and partial cross-sectional perspective view of the relevant components of the scroll compressor necessary for illustrating an injection valve assembly of the scroll compressor;

FIG. **4** is a partially exploded perspective view of the injection valve assembly of FIG. **3** with an injection plate thereof separated from a reed structure, a valve gasket, and a valve body thereof;

FIG. **5** is an axial end elevational view of the reed structure, the valve gasket, and the valve body shown in the absence of the injection plate;

FIG. **6** is a cross-sectional elevational view of the reed structure, the valve gasket, and the valve body as taken from the perspective of section lines **6-6** in FIG. **5**;

FIG. **7** is a fragmentary cross-sectional perspective view of the reed structure, the valve gasket, and the valve body as taken from the perspective of section lines **7-7** in FIG. **5**;

FIG. **8** is a partially exploded perspective view of an injection valve assembly according to another embodiment of the present invention with an injection plate thereof separated from a reed structure and a valve body thereof;

FIG. **9** is a perspective view of the reed structure and the valve body of the injection valve assembly of FIG. **8**;

FIG. **10** is an axial end elevational view of the reed structure and the valve body of the injection valve assembly of FIG. **8**;

FIG. **11** is a fragmentary cross-sectional perspective view of the reed structure and the valve body as taken from the perspective of section lines **11-11** in FIG. **10**; and

FIG. **12** is a fragmentary cross-sectional perspective view of the reed structure and the valve body as taken from the perspective of section lines **12-12** in FIG. **10**.

DETAILED DESCRIPTION OF THE INVENTION

The following detailed description and appended drawings describe and illustrate various embodiments of the invention. The description and drawings serve to enable one skilled in the art to make and use the invention, and are not intended to limit the scope of the invention in any manner.

FIGS. **1-7** illustrate the relevant portions of a vapor injection scroll compressor **1** having an injection valve assembly **20** according to an embodiment of the present invention. As used hereinafter, the vapor injection scroll compressor **1** is referred to as the scroll compressor **1** while the injection valve assembly **20** is referred to as the valve assembly **20**. The scroll compressor **1** may be provided as a component of an HVAC system of a motor vehicle, and more particularly, a component for circulating a refrigerant of an associated refrigerant circuit in heat exchange communication with air to be delivered to the passenger compartment of the associated motor vehicle. The refrigerant may also be in heat exchange relationship with additional components of the motor vehicle in need of heat regulation, such as a battery or other electronic components associated with operation of various different systems of the motor vehicle. References to the refrigerant as used hereinafter may refer to a refrigerant when provided solely as a gas or as a mixture of a gas and a liquid. Although the scroll compressor **1** is described as being utilized for a refrigerant of an HVAC system, it should be apparent that the structure disclosed herein may be adapted for use with any fluid in need of compression with respect to any associated fluid system, as desired.

As best shown in cross-section in FIG. **1**, the scroll compressor **1** includes a compression mechanism formed by a fixed scroll **5** having an axially extending first spiral structure **6** and an orbiting scroll **7** having an axially extending second spiral structure **8**. The second spiral structure **8** extends in an opposing axial direction relative to the first spiral structure **6** with each of the spirals of the second spiral structure **8** nested into each of the spaces formed between adjacent spirals of the first spiral structure **6**. The first spiral structure **6** and the second spiral structure **8** are positioned relative to each other to form a plurality of compression chambers **9** therebetween during operation of the compression mechanism of the scroll compressor **1**.

The fixed scroll **5** includes at least one inlet opening **11** adjacent a radially outermost portion thereof for introducing the refrigerant into each of the compression chambers **9**. In the provided embodiment, the fixed scroll **5** includes a plurality of the inlet openings **11** circumferentially spaced apart from each other in an outer circumferential wall **12** of the fixed scroll **5** with each of the inlet openings **11** provided as a hole, indentation, or other form of passageway allowing for radially inward flow of the refrigerant into one of the compression chambers **9**. The refrigerant generally enters the fixed scroll **5** through one of the inlet openings **11** at a relatively low pressure typically referred to as a suction pressure of the scroll compressor **1**. The fixed scroll **5** further includes a discharge opening **13** formed at a radial innermost end of the first spiral structure **6** through which the refrigerant exits each of the compression chambers **9** after having been compressed therein. The discharge opening **13** is accordingly located at or adjacent a radial center of the fixed scroll **5**. The compressed refrigerant thereby exits the cooperating scrolls **5**, **7** at a relatively high pressure that is greater than the relatively low pressure suction pressure, wherein the relatively high pressure is referred to as the discharge pressure of the scroll compressor **1**.

The orbiting scroll **7** is configured to orbit relative to the fixed scroll **5** in a manner wherein each of the compression chambers **9** progresses circumferentially and radially inwardly towards the discharge opening **13**. A shape and position of each of the compression chambers **9** accordingly changes relative to the fixed shape and position of the fixed scroll **5** during the repeating orbiting motion of the orbiting scroll **7**. This motion causes each of the compression chambers **9** to reduce in flow volume as each of the compression chambers **9** approaches the radially inwardly disposed discharge opening **13**, thereby causing the previously discussed compression of the refrigerant.

FIG. **1** illustrates the cross-section through the fixed scroll **5** and the orbiting scroll **7** when the compression mechanism is at a position having two pairs of opposing compression chambers **9**. Each of the compression chambers **9** forming one of the pairs includes substantially the same shape rotated 180 degrees relative to the other of the paired and opposing compression chambers **9**. A first pair of the compression chambers **9** is disposed immediately adjacent a radial center of each of the spiral structures **6**, **8** (generally corresponding to the position of the discharge opening **13**) while a second pair of the compressions chambers **9** is formed radially outwardly of the first pair of the compression chambers **9** closer to the inlet openings **11**.

The fixed scroll **5** includes an end wall **14** including an inner face **15** and an opposing outer face **16**. The inner face **15** faces towards the orbiting scroll **7** with the first spiral structure **6** extending axially from the inner face **15**. The outer face **16** faces away from the orbiting scroll **7** and faces towards the previously mentioned valve assembly **20** (shown in FIG. **3**). The discharge opening **13**, a first injection port **17**, and a second injection port **18** are all formed through the end wall **14** from the inner face **15** to the outer face **16** thereof. FIG. **2** shows the inner face **15** of the end wall **14** with the orbiting scroll **7** omitted to better illustrate the positioning of the discharge opening **13** and the injection ports **17**, **18** relative to the configuration of the first spiral structure **6**.

The first injection port **17** is positioned substantially opposite the second injection port **18** relative to the centrally disposed discharge opening **13**, with each of the injection ports **17**, **18** also spaced radially at a substantially equal distance from the discharge opening **13**. The substantially opposite positioning of the injection ports **17**, **18** allows for the first injection port **17** to fluidly communicate with a first one of each of the oppositely paired compression chambers **9** and the second injection port **18** to fluidly communicate with a second one of each of the oppositely paired compression chambers **9**. As such, each of the compression chambers **9** progressing radially inwardly towards the discharge opening **13** is able to fluidly communicate with one of the injection ports **17**, **18** at a substantially similar radial position relative to the discharge opening **13**, which also corresponds to the refrigerant disposed within each of the opposing and paired compression chambers **9** having a similar pressure when fluidly communicating with the corresponding one of the injection ports **17**, **18**. The pressure of the refrigerant when reaching each of the injection ports **17**, **18** may be referred to as an intermediate pressure having a value between the previously described suction pressure and discharge pressure.

Referring now to FIG. **3**, the components of the scroll compressor **1** relevant to the operation of the valve assembly **20** are shown in exploded view for more easily ascertaining the method of assembly thereof. The orbiting scroll **7** and the components necessary for causing the orbiting motion thereof are omitted, but one skilled in the art should readily appreciate that the method of operation of the valve assembly **20** is apparent from the illustrated perspective in their absence.

A rear housing **110** of the scroll compressor **1** is an open ended and hollow structure configured to mate with a front housing (not shown) of the scroll compressor **1** for enclosing the internal components thereof. The rear housing **110** defines a housing opening **111** configured to receive the fixed scroll **5** and the valve assembly **20** therein. One skilled in the art should appreciate that alternative configurations of the housing components of the scroll compressor **1** may be provided so long as the relevant structures for directing the flow of the refrigerant are maintained as described hereinafter, including the use of additional housing components or the use of housing components having alternatively arranged joints present therebetween. More specifically, any combination of housing components may be utilized so long as the housing opening **111** is provided to receive the fixed scroll **5** and the valve assembly **20** therein in a manner promoting operation of the valve assembly **20** as disclosed hereinafter.

The housing opening **111** is in fluid communication with a refrigerant return passage **112**. The refrigerant return passage **112** provides fluid communication between the housing opening **111** and another component (not shown) of the associated refrigerant circuit through which the refrigerant is passed after being initially compressed within the compression mechanism of the scroll compressor **1**. For example, the component may be a separator (not shown) disposed downstream of the compression mechanism and upstream of a low pressure side of the scroll compressor **1** with respect to a general direction of flow of the refrigerant through the refrigerant circuit, such as a cyclone separator. The refrigerant return passage **112** is configured to receive a partial flow of the refrigerant after branching away from the refrigerant circuit. The partial flow of the refrigerant may have a pressure between the discharge pressure and the suction pressure and may bypass at least one component of the refrigerant circuit disposed upstream of the low pressure side of the scroll compressor **1**. In some instances, the component from which the refrigerant branches back towards the refrigerant return passage **112** may be disposed immediately downstream of the compression mechanism and even from a downstream arranged portion of the scroll compressor **1** itself. One skilled in the art should appreciate that the refrigerant may return to the refrigerant return passage **112** from any component of the refrigerant circuit while remaining within the scope of the present invention so long as the refrigerant has the required characteristics for being injected back into the compression chambers **9** during the compression process occurring within the compression mechanism.

The refrigerant return passage **112** leads to an injection chamber **113** of the rear housing **110**. The injection chamber **113** is an open space provided as a portion of the housing opening **111** disposed between the refrigerant return passage **112** and the valve assembly **20**. The refrigerant entering the injection chamber **113** may be a gaseous vapor or a combination of a gaseous vapor and a liquid, depending on the circumstances of the returned refrigerant.

A first gasket **115** is disposed between a periphery of the outer face **16** of the fixed scroll **5** and an inner surface of the rear housing **110** defining the housing opening **111** thereof. The fixed scroll **5** is received into the housing opening **111** with the first gasket **115** compressed between the outer face **16** and the inner surface of the rear housing **110** for creating a seal in a manner wherein refrigerant cannot flow around a periphery of the fixed scroll **5** to isolate the injection chamber **113** and the valve assembly **20** from the low pressure side of the scroll compressor **1**. The valve assembly **20** is disposed between the outer face **16** and the refrigerant return passage **112** with the outwardly facing surfaces thereof exposed to the refrigerant entering the injection chamber **113** through the refrigerant return passage **112**.

The valve assembly **20** includes an injection plate **22**, a double reed structure **30**, a valve gasket **50**, and a valve body **80**, wherein the components are disposed in the provided order when progressing from the refrigerant return passage **112** towards the fixed scroll **5**. The direction of assembly of the valve assembly **20** as shown by the direction of separation of the components forming the valve assembly **20** in the exploded view of FIG. **3** is hereinafter referred to as an axial direction of the valve assembly **20**. The axial direction of the valve assembly **20** also corresponds to the axial direction of each of the constituent components thereof as used hereinafter.

The injection plate **22** includes a substantially planar first major surface **23** and an oppositely arranged and also substantially planar second major surface **24**, wherein the major surfaces **23**, **24** are arranged parallel to each other and perpendicular to the axial direction of the valve assembly **20**. The first major surface **23** faces towards the refrigerant return passage **112** and the second major surface **24** faces towards the reed structure **30** and the valve gasket **50**.

The injection plate **22** includes a first injection hole **25** and a spaced apart second injection hole **26**. Each of the injection holes **25**, **26** extends through the injection plate **22** with respect to the axial direction from the first major surface **23** to the second major surface **24** thereof. A spacing between the injection holes **25**, **26** with respect to a direction perpendicular to the axial direction may be substantially similar to or equal to a spacing between the first injection port **17** and the second injection port **18** formed through the fixed scroll **5**.

Each of the injection holes **25**, **26** is shown as having an elongated perimeter shape with a direction of elongation of each of the injection holes **25**, **26** arranged in parallel. The injection holes **25**, **26** may otherwise be referred to as injection slots **25**, **26** due to the elongated configurations thereof. Each of the injections holes **25**, **26** is shown as having an elongate stadium shape, but other rounded and elongate shapes may be utilized such as an elliptical shape, oval shape, rounded rectangular shape, or the like. The elongate shape of each of the injection holes **25**, **26** beneficially provides for an increased cross-sectional flow area therethrough in comparison to a purely circular cross-sectional shape, which in turn increases the total force that can be applied by the returned refrigerant through each of the injection holes **25**, **26** with respect to a given pressure of the refrigerant. However, other shapes, including the circular shape, may be utilized while still appreciating the remaining beneficial characteristics of the valve assembly **20**.

A second gasket **116** is disposed between a periphery of the first major surface **23** and the inner surface of the rear housing **110** defining the housing opening **111**. The second gasket **116** provides a seal between the injection plate **22** and the rear housing **110** to prevent refrigerant from bypassing the flow paths formed through the valve assembly **20** and fluidly communicating with the compression chambers **9** of the scrolls **5**, **7**.

The injection plate **22** is generally rectangular in shape with each of the four corners of the rectangular shape including a fastener opening **27** formed therethrough. The fastener openings **27** are disposed outwardly from a position of the perimeter of the second gasket **116** when sealingly engaging the injection plate **22**. As shown in FIG. **3**, each of the fastener openings **27** is configured to axially receive a corresponding threaded fastener **117** for coupling and compressing the components of the valve assembly **20** together as explained in greater detail hereinafter. An end of each of the threaded fasteners **117** may be inserted into one of four corresponding threaded openings (not shown) provided in the surface of the rear housing **110** defining the housing opening **111**. Alternative coupling methods may also be utilized so long as the components forming the valve assembly **20** are compressed to one another for forming the necessary fluid tight seals therebetween while maintaining the relationships between the components as explained hereinafter.

The injection plate **22** also includes a pair of spaced apart locating openings **28** formed therethrough. Each of the locating openings **28** is configured to receive a corresponding locating feature **118** therethrough when the valve assembly **20** is in the assembled configuration. The locating features **118** may be threaded fasteners, pins, or the like. The use of two of more of the locating openings **28** ensures that the components of the valve assembly **20** do not translate in a direction perpendicular to the axial direction thereof or rotate about an axis arranged parallel to the axial direction thereof. However, other locating features such as cooperating projections and indentations may be present within the components forming the valve assembly **20** while remaining within the scope of the present invention.

The injection plate **22** is formed from a rigid material resistant to deformation when subjected to the pressure applied by the returned refrigerant entering the injection chamber **113**. The injection plate **22** may be formed from a metallic material such as aluminum, aluminum alloy, steel, or the like, as desired.

The double reed structure **30** is a thin and planar plate-like body including a first major surface **31** and an oppositely arranged second major surface **32** (best shown in FIG. **6**). The major surfaces **31**, **32** are arranged parallel to each other and perpendicular to the axial direction of the valve assembly **20**. The first major surface **31** is configured to face towards and engage the second major surface **24** of the injection plate **22** and the second major surface **32** is configured to face towards and engage the valve gasket **50** as explained in greater detail hereinafter.

The double reed structure **30** includes a first reed **33**, a second reed **34**, and a connecting portion **35**. The reeds **33**, **34** and the connecting portion **35** are integrally formed as one monolithic structure. The first reed **33** and the second reed **34** normally extend longitudinally away from the connecting portion **35** in opposing parallel directions perpendicular to the axial direction of the valve assembly **20** when the reeds **33**, **34** are not flexed during operation of the scroll compressor **1**. In the provided embodiment, the reeds **33**, **34** and the connecting portion **35** cooperate to have a substantially Z-shaped configuration, but the connecting portion **35** may have any shape or configuration so long as the connecting portion **35** extends between and connects the reeds **33**, **34** to form the described unitary structure with the reeds **33**, **34** arranged in the illustrated staggered configuration.

The first reed **33** includes an arm **37** extending longitudinally between a pivot portion **38** and an end portion **39**. The pivot portion **38** forms an axis about which the remainder of the first reed **33** (including the end portion **39** disposed at a distal end of the arm **37** opposite the pivot portion **38**) flexes relative to the stationary connecting portion **35**. The end portion **39** is disposed in alignment with the first injection hole **25** of the injection plate **22** with respect to the axial direction of the valve assembly **20**. The arm **37** may include a substantially rectangular shape while the end portion **39** may include a substantially similar perimeter shape to the first injection hole **25**. For example, the end portion **39** may include an elongate stadium shape, elliptical shape, oval shape, rounded rectangular shape, or the like to ensure that the end portion **39** is capable of covering the first injection hole **25** when engaging the injection plate **22** around a periphery of the first injection hole **25**.

The second reed **34** includes an arm **41** extending longitudinally between a pivot portion **42** and an end portion **43**. The pivot portion **42** forms an axis about which the remainder of the second reed **34** (including the end portion **43** disposed at a distal end of the arm **41** opposite the pivot portion **42**) flexes relative to the stationary connecting portion **35**. The end portion **43** is disposed in alignment with the second injection hole **26** of the injection plate **22** with respect to the axial direction of the valve assembly **20**. The arm **41** may include a substantially rectangular shape while the end portion **43** may include a substantially similar perimeter shape to the second injection hole **26**. For example, the end portion **43** may include an elongate stadium shape, elliptical shape, oval shape, rounded rectangular shape, or the like to ensure that the end portion **43** is capable of covering the second injection hole **26** when engaging the injection plate **22** around a periphery of the second injection hole **26**.

The double reed structure **30** further includes a pair of locating openings **48** disposed in outwardly disposed regions of the connecting portion **35** formed at opposing corners thereof. Each of the pair of the locating openings **48** is disposed in alignment with a corresponding one of the locating openings **28** of the injection plate **22**. Each of the locating openings **48** is configured to receive a corresponding one of the locating features **118** therethrough when the valve assembly **20** is in the assembled configuration to properly position the double reed structure **30** relative to the injection plate **22** as well as the valve gasket **50**.

The double reed structure **30** is formed from a resiliently flexible material allowing for each of the arms **37**, **41** of the reeds **33**, **34** to flex about the respective pivot portions **38**, **42** away from the plane generally defined by the double reed structure **30**. The resiliently flexible material is selected to allow for repeated elastic deformations of each of the reeds **33**, **34** about the pivot portions **38**, **42** while still allowing for each of the reeds **33**, **34** to spring back to the original positions thereof wherein the reeds **33**, **34** are arranged perpendicular to the axial direction of the valve assembly **20** and parallel to the major surfaces **31**, **32** of the connecting portion **35** of the double reed structure **30**. The flexing of each of the reeds **33**, **34** away from the corresponding injection hole **25**, **26** requires a force being applied to each of the reeds **33**, **34** that overcomes a spring force generated by the resiliency of each of the reeds **33**, **34** at each of the corresponding pivot portions **38**, **42**. The double reed structure **30** may accordingly be formed from a suitable metallic material such as aluminium, steel, or alloys thereof.

The valve gasket **50** includes a planar portion **51** having a thin and plat-like configuration with the planar portion **51** having a first major surface **53** and an oppositely arranged second major surface **54** (best shown in FIG. **6**), each of which is arranged substantially perpendicular to the axial direction of the valve assembly **20**. The first major surface **53** is configured to face towards and sealingly engage the second major surface **32** of the double reed structure **30** and the second major surface **54** is configured to face towards and sealingly engage a first major surface **81** of the valve body **80** (FIG. **6**). More specifically, the first major surface **53** of the planar portion **51** is configured to sealingly engage the stationary and non-flexing connecting portion **35** of the double reed structure **30**. The first major surface **53** further includes a bead **52** projecting axially from a periphery thereof with the bead **52** configured to sealingly engage the second major surface **24** of the injection plate **22** about a periphery thereof. The bead **52** engages the second major surface **24** peripherally to surround the injection holes **25**, **26** and the locating openings **28** of the injection plate **22**. The bead **52** projects from the remainder of the first major surface **53** a suitable axial distance to account for the thickness of the intervening double reed structure **30** when establishing the engagement with the injection plate **22**.

The valve gasket **50** further includes a first flap **55** and a second flap **65**, each of which extends from and is formed continuous with the planar portion **51** of the valve gasket **50**. In other words, the planar portion **51**, the first flap **55**, and the second flap **65** are all formed integrally as part of a unitary and monolithic structure. The first flap **55** and the second flap **65** each extend away from the planar portion **51** in opposing and parallel directions. The first flap **55** is aligned with the first reed **33** with respect to the axial direction of the valve assembly **20** and the second flap **65** is aligned with the second reed **34** with respect to the axial direction of the valve assembly **20**.

The first flap **55** includes a proximate end **56** connected to and continuous with the planar portion **51** and a freely disposed distal end **57**. The first flap **55** further includes a contact surface **58** (FIG. **6**) formed continuous with the first major surface **53** of the planar portion **51** with the contact surface **58** facing towards the first reed **33** of the double reed structure **30**. The first flap **55**, and more specifically the contact surface **58** thereof, is arranged at an incline relative to the plane of the planar portion **51** with the first flap **55** inclined away from the injection plate **22** and towards the valve body **80**. The incline includes an axial distance present between the contact surface **58** and the connecting portion **35** of the double reed structure **30** progressively increasing as the first flap **55** extends from the proximate end **56** to the distal end **57**. The contact surface **58** is configured to engage the first reed **33** when the first reed **33** is flexed or pivoted towards the contact surface **58** as a result of the pressure applied thereto by the refrigerant passing through the valve assembly **20**. The contact surface **58** may include a substantially similar shape to the first reed **33** and may include a slightly larger size than the first reed **33** to ensure that the first reed **33** makes consistent contact with the contact surface **58** each time the first reed **33** is flexed towards the contact surface **58**. The incline of the contact surface **58** may be substantially constant, but may also include a slight curvature to account for any curvature present in the first reed **33** as a result of the flexing thereof. The incline of the contact surface **58** may be at an angle of about 3-5 degrees relative to the plane of the planar portion **51**, but other angles of inclination may be utilized while remaining within the scope of the present invention.

As best shown in FIG. **5**, the inclined deviation of the first flap **55** from the planar portion **51** includes the formation of a peripheral opening **60** around at least a portion of the perimeter of the first flap **55**. The peripheral opening **60** is configured to allow for passage of the refrigerant through the valve gasket **50** when progressing towards the valve body **80**. In the provided embodiment, the peripheral opening **60** is subdivided into a pair of proximate openings **61** adjacent the proximate end **56** and a distal opening **62** extending around the distal end **57**, wherein the distal opening **62** is separated from the proximate openings **61** via a pair of opposing linking segments **63** connecting the planar portion **51** to the first flap **55** at opposing positions intermediate the proximate end **56** and the distal end **57** thereof. The linking segments **63** provide stiffness and stability to the first flap **55** to maintain the configuration of the first flap **55** when the first reed **33** flexes towards and engages the first flap **55**.

The second flap **65** includes a proximate end **66** connected to and continuous with the planar portion **51** and a freely disposed distal end **67**. The second flap **65** further includes a contact surface **68** formed continuous with the first major surface **53** of the planar portion **51** with the contact surface **58** facing towards the second reed **34** of the double reed structure **30**. The second flap **65**, and more specifically the contact surface **68** thereof, is arranged at an incline relative to the plane of the planar portion **51** with the second flap **65** inclined away from the injection plate **22** and towards the valve body **80**. The incline includes an axial distance present between the contact surface **68** and the connecting portion **35** of the double reed structure **30** progressively increasing as the second flap **65** extends from the proximate end **66** to the distal end **67**. The contact surface **68** is configured to engage the second reed **34** when the second reed **34** is flexed or pivoted towards the contact surface **68** as a result of the pressure force applied thereto by the refrigerant passing through the valve assembly **20**. The contact surface **68** may include a substantially similar shape to the second reed **34** and may include a slightly larger size than the second reed **34** to ensure that the second reed **34** makes consistent contact with the contact surface **68** each time the second reed **34** is flexed towards the contact surface **68**. The incline of the contact surface **68** may be substantially constant, but may also include a slight curvature to account for any curvature present in the second reed **34** as a result of the flexing thereof. The incline of the contact surface **68** may be at an angle of about 3-5 degrees relative to the plane of the planar portion **51**, but other angles of inclination may be utilized while remaining within the scope of the present invention.

The inclined deviation of the second flap **65** from the planar portion **51** includes the formation of a peripheral opening **70** around at least a portion of the perimeter of the second flap **65**. The peripheral opening **70** is configured to allow for passage of the refrigerant through the valve gasket **50** when progressing towards the valve body **80**. In the provided embodiment, the peripheral opening **70** is subdivided into a pair of proximate openings **71** adjacent the proximate end **66** and a distal opening **72** extending around the distal end **67**, wherein the distal opening **72** is separated from the proximate openings **71** via a pair of opposing linking segments **73** connecting the planar portion **51** to the second flap **65** at opposing positions intermediate the proximate end **66** and the distal end **67** thereof. The linking segments **73** provide stiffness and stability to the second flap **65** to maintain the configuration of the second flap **65** when the second reed **34** flexes towards and engages the second flap **65**.

The valve gasket **50** includes four fastener openings **77** formed therethrough at positions exterior to the bead **52**. Each of the four fastener openings **77** is disposed in alignment with a corresponding one of the fastener openings **27** of the injection plate **22** and is configured to receive a corresponding one of the threaded fasteners **117** therethrough. The valve gasket **50** further includes a pair of locating openings **78** formed therethrough at positions interior to the bead **52**. Each of the pair of the locating openings **78** is disposed in alignment with a corresponding one of the locating openings **48** of the double reed structure **30** and is configured to receive a corresponding one of the locating features **118** therethrough.

The entirety of the valve gasket **50** (including the planar portion **51**, the bead **52**, the first flap **55**, and the second flap **65**) is formed from a resiliently compressible material suitable for sealingly engaging each of the corresponding surfaces of the injection plate **22**, the double reed structure **30**, and the valve body **80** as described above. The valve gasket **50** may be formed (molded) from a polymeric material such as an elastomer, as desired. The use of the elastomeric material in forming the valve gasket **50** prevents repeated metal-to-metal contact with the reeds **33**, **34** during operation of the scroll compressor **1**, which increases a durability of the double reed structure **30** due to the relative softness of the elastomeric material in comparison to a stiff metallic material.

The valve body **80** includes a periphery of the first major surface **81** thereof configured to engage a periphery of the second major surface **54** of the planar portion **51**. The periphery of the first major surface **81** is arranged perpendicular to the axial direction of the valve assembly **20**. A second major surface **82** of the valve body **80** formed opposite the first major surface **81** faces towards the outer face **16** of the fixed scroll **5**. The first major surface **81** includes a first indentation **85** (FIG. **6**) and a spaced apart second indentation **95** (FIG. **7**) formed therein with the indentations **85**, **95** extending longitudinally in parallel to each other in a staggered configuration.

The first indentation **85** is disposed in alignment with the first flap **55** with respect to the axial direction of the valve assembly **20** with at least a portion of the inclined first flap **55** extending into the first indentation **85**. The first indentation **85** is defined by a surface **86** inclined at an angle relative to the plane of the periphery of the first major surface **81**. The surface **86** extends from a proximate end **87** disposed adjacent the proximate end **56** of the first flap **55** to a distal end **88** disposed adjacent the distal end **57** of the first flap **55**. An axial depth of the first indentation **85** increases as the surface **86** progresses from the proximate end **87** to the distal end **88** thereof to cause the distal end **88** to have a maximized depth towards the fixed scroll **5**. The angle of inclination of the surface **86** may substantially correspond to the angle of inclination of the first flap **55**, such as being inclined at about 3-5 degrees, but alternative configurations may be utilized without necessarily departing from the scope of the present invention.

The extension of the first flap **55** into the first indentation **85** divides the first indentation **85** into a first flow space **89** between the first flap **55** and the plane defined by the periphery of the first major surface **81** and a second flow space **91** between the first flap **55** and the inclined portion of the surface **86**. Any refrigerant present within the first flow space **89** is able to flow through the valve gasket **50** to the second flow space **91** by flowing through the peripheral opening **60** surrounding the first flap **55**.

The second major surface **82** of the valve body **80** includes a first post **83** projecting axially therefrom and towards the fixed scroll **5**. A first flow passageway **92** is formed through the valve body **80** and extends from the first indentation **85** to an axial end of the first post **83** engaging the fixed scroll **5** around a periphery of the first injection port **17**. The first flow passageway **92** provides fluid communication between the first indentation **85** and the first injection port **17** of the fixed scroll **5**. An O-ring or similar sealing element (not shown) may be disposed between an end portion of the first post **83** and the outer face **16** of the fixed scroll **5** or a surface defining the first injection port **17** to fluidly seal the joint therebetween. The first flow passageway **92** may extend from the distal end **88** of the surface **86** defining the first indentation **85** at a position offset from the distal end **57** of the first flap **55** with respect to a direction perpendicular to the axial direction of the valve assembly **20**. The offset may be present to prevent too great of a change of direction of the refrigerant when flowing from the distal end **57** of the first flap **55** towards the first flow passageway **92**. The first indentation **85** and the first flow passageway **92** accordingly cooperate to form a first flow path through the valve body **80** configured for fluid communication with the first injection port **17**.

The first flow passageway **92** is formed from a first segment **93** extending from the surface **86** of the first indentation **85** and a second segment **94** (shown in phantom lines in FIG. **6**) extending to the end of the first post **83**. The configuration of the first flow passageway **92** may be best understood by review of a second flow passageway **102** associated with the second indentation **95** as shown in FIG. **7**, due to each of the flow paths **92**, **102** having substantially identical configurations. The first segment **93** and the second segment **94** are each shown as having a substantially cylindrical shape for forming a substantially circular cross-sectional flow area through each of the segments **93**, **94**, but alternative configurations may be utilized without necessarily departing from the scope of the present invention. The first segment **93** includes a first diameter that is greater than a second diameter of the second segment **94**, thus the first segment **93** includes a greater cross-sectional flow area than the second segment **94**. The first segment **93** having a larger cross-sectional area than the second segment **94** reduces a pressure drop experienced by the refrigerant when flowing through the first flow passageway **92** to minimize flow losses during operation of the valve assembly **20**. Additionally, the cross-sectional flow area through the first indentation **85** immediately upstream of the first flow passageway **92** is also greater than that of the first segment **93** thereof, thereby further ensuring the absence of the pressure drop and flow loss.

The first segment **93** and the second segment **94** may be disposed at an angle relative to each other. In the illustrated embodiment, the first segment **93** is inclined relative to the axial direction of the valve assembly **20** while the second segment **94** is axially aligned with the first injection port **17** and arranged parallel to the axial direction of the valve assembly **20**.

The second indentation **95** is disposed in alignment with the second flap **65** with respect to the axial direction of the valve assembly **20** with at least a portion of the inclined second flap **65** extending into the second indentation **95**. The second indentation **95** is defined by a surface **96** inclined at an angle relative to the plane of the periphery of the first major surface **81**. The surface **96** extends from a proximate end **97** disposed adjacent the proximate end **66** of the second flap **65** to a distal end **98** disposed adjacent the distal end **67** of the second flap **65**. An axial depth of the second indentation **95** increases as the surface **96** progresses from the proximate end **97** to the distal end **98** thereof to cause the distal end **98** to have a maximized depth towards the fixed scroll **5**. The angle of inclination of the surface **96** may substantially correspond to the angle of inclination of the second flap **65**, such as being inclined at about 3-5 degrees, but alternative configurations may be utilized without necessarily departing from the scope of the present invention.

The extension of the second flap **65** into the second indentation **95** divides the second indentation **95** into a first flow space **99** between the second flap **65** and the plane defined by the periphery of the first major surface **81** and a second flow space **101** between the second flap **65** and the inclined portion of the surface **96**. Any refrigerant present within the first flow space **99** is able to flow through the valve gasket **50** to the second flow space **101** by flowing through the peripheral opening **70** surrounding the second flap **65**.

The second major surface **82** of the valve body **80** includes a second post **84** projecting axially therefrom and towards the fixed scroll **5**. The second flow passageway **102** is formed through the valve body **80** and extends from the second indentation **95** to an axial end of the second post **84** engaging the fixed scroll **5** around a periphery of the second injection port **18**. The second flow passageway **102** provides fluid communication between the second indentation **95** and the second injection port **18** of the fixed scroll **5**. An O-ring or similar sealing element (not shown) may be disposed between the end portion of the second post **84** and the outer face **16** of the fixed scroll **5** or a surface of the second injection port **18** to fluidly seal the joint therebetween. The second flow passageway **102** may extend from the distal end **98** of the surface **96** defining the second indentation **95** at a position offset from the distal end **67** of the second flap **65** with respect to a direction perpendicular to the axial direction of the valve assembly **20**. The offset may be present to prevent too great of a change of direction of the refrigerant when flowing from the distal end **67** of the second flap **65** towards the second flow passageway **102**. The second indentation **95** and the second flow passageway **102** accordingly cooperate to form a second flow path through the valve body **80** configured for fluid communication with the second injection port **18**.

The second flow passageway **102** is formed from a first segment **103** extending from the surface **96** of the second indentation **95** and a second segment **104** extending to the end of the second post **84**. The first segment **103** and the second segment **104** are each shown as having a substantially cylindrical shape for forming a substantially circular cross-sectional flow area through each of the segments **103**, **104**, but alternative configurations may be utilized without necessarily departing from the scope of the present invention. The first segment **103** includes a first diameter that is greater than a second diameter of the second segment **104**, thus the first segment **103** includes a greater cross-sectional flow area than the second segment **104**. The first segment **103** having a larger cross-sectional area than the second segment **104** reduces a pressure drop experienced by the refrigerant when flowing through the second flow passageway **102** to minimize flow losses during operation of the valve assembly **20**. Additionally, the cross-sectional flow area through the second indentation **95** immediately upstream of the second flow passageway **102** is also greater than that of the first segment **103** thereof, thereby further ensuring the absence of the pressure drop and flow loss.

The first segment **103** and the second segment **104** may be disposed at an angle relative to each other. In the illustrated embodiment, the first segment **103** is inclined relative to the axial direction of the valve assembly **20** while the second segment **104** is axially aligned with the second injection port **18** and arranged parallel to the axial direction of the valve assembly **20**.

The valve body **80** includes four fastener openings **107** formed therethrough about a periphery thereof with each of the four fastener openings **107** disposed in alignment with a corresponding one of the fastener openings **77** of the valve gasket **50** and configured to receive a corresponding one of the threaded fasteners **117** therethrough. The valve body **80** further includes a pair of locating openings **108** formed therethrough with each of the pair of the locating openings **108** disposed in alignment with a corresponding one of the locating openings **78** of the valve gasket **50** and configured to receive a corresponding one of the locating features **118** therethrough.

The valve body **80** is formed from a rigid material resistant to deformation when subjected to the pressure applied by the refrigerant passing through the valve assembly **20**. The valve body **80** may be formed from a metallic material such as aluminum, aluminum alloy, steel, or the like, as desired.

Operation of the valve assembly **20** is now described. Because the flow configuration of the refrigerant is substantially identical with respect to each of the partial refrigerant flows entering each of the injection ports **17**, **18**, only the partial refrigerant flow passing from the first injection hole **25** to the first injection port **17** is described in detail hereinafter with the understanding that the corresponding and analogous components associated with the other partial refrigerant flow passing from the second injection hole **26** to the second injection port **18** operate in the same manner.

During operation of the scroll compressor **1**, at least a portion of the refrigerant discharged from the compression mechanism formed by the cooperating scrolls **5**, **7** is returned back to the injection chamber **113** via the refrigerant return passage **112**. The end portion **39** of the first reed **33** is configured to normally extend across and cover the first injection hole **25** to prevent undesired flow of the returned refrigerant from the injection chamber **3** and towards the first injection port **17**. The compression mechanism of the scroll compressor **1** operates to cause the first injection port **17** to repeatedly experience a variable pressure of the refrigerant within the compression mechanism depending on the progression of each subsequent compression chamber **9** passing by the first injection port **17**.

When the variable pressure experienced by the first injection port **17** from the refrigerant originating from within the compression mechanism is relatively high, the end portion **39** of the first reed **33** is maintained against the surface of the injection plate **22** surrounding the first injection hole **25** to continue to prevent the passage of the refrigerant within the injection chamber **113** towards the first injection port **17**. However, when the variable pressure experienced by the first injection port **17** from the refrigerant originating from within the compression mechanism is relatively low, the pressure of the refrigerant within the injection chamber **113** eventually exceeds the relatively low pressure originating from the compression mechanism and a pressure differential is established across the opposing surfaces of the end portion **39** of the first reed **33**. When the force of the pressure of the refrigerant within the injection chamber **113** exceeds the combined force of the pressure of the refrigerant originating from the compression mechanism and a spring force generated by a resiliency of the first reed **33** at the pivot portion **38** thereof, the first reed **33** pivots about the axis defined by the pivot portion **38** and towards the valve body **80**. The pivoting of the first reed **33** causes the refrigerant within the injection chamber **113** to pass through the first injection hole **25** and around the now axially spaced end portion **39** of the first reed **33**. The first reed **33** may pivot until encountering the contact surface **58** of the first flap **55** of the valve gasket **50**, which provides a relatively soft stop limiting the rotation of the first reed **33**.

The refrigerant originating from the injection chamber **113** then proceeds through the open space formed by the first indentation **85** of the valve body **80** while passing through the valve gasket **50** via the peripheral opening **60** surrounding the first flap **55**. The refrigerant then flows towards and passes through the first flow passageway **92** and into the first injection port **17**. The refrigerant is then injected into the corresponding compression chamber **9** while having a higher pressure than the refrigerant already disposed within the compression chamber **9** and originating from one of the inlet openings **11** of the fixed scroll **5**, which allows for the compression capacity of the scroll compressor **1** to be increased by reintroducing higher pressure refrigerant into the compression mechanism at an intermediate position of the compression process.

The first reed **33** eventually resiliently springs back to the position blocking flow from the injection chamber **113** through the valve assembly **20** based on the cycling of the compression mechanism and the resulting pressure differential on the opposing sides of the first reed **33**. The valve assembly **20** accordingly acts a check valve for preventing a flow of the refrigerant in an undesired direction relative to the first reed **33**, which in turn prevents the refrigerant originating from the compression mechanism backflowing into the injection chamber **113** in an undesired flow direction. The described process is repeatedly performed as the pressure experienced by the first injection port **17** is varied with respect to each passing compression chamber **9** formed by the orbiting of the orbiting scroll **7** relative to the fixed scroll **5**.

The valve assembly **20** as shown and described offers numerous advantageous features. As is apparent from a review of FIGS. **3-5**, a first half of the valve assembly **20** having the components associated with the partial flow towards the first injection port **17** and a second half of the valve assembly **20** having the components associated with the partial flow towards the second injection port **18** are substantially structurally identical with the second half rotated 180 degrees relative to the first half with respect to a central axis passing through the valve assembly **20**, wherein the central axis substantially corresponds to the position of the discharge opening **13** of the fixed scroll **5** and the position at which the refrigerant return passageway **112** intersects the injection chamber **113**. This staggered and 180 degree rotated relationship between the two partial flows results in a more even distribution of the refrigerant to each of the injection ports **17**, **18** as each of the partial flows experiences substantially similar flow conditions and flow path lengths. The elongation of each of the injection holes **25**, **26** allows for a greater pressure force to be applied to each of the reeds **33**, **34** for selectively actuating the reeds **33**, **34**. The unitary formation of the double reed structure **30** simplifies the manufacturing of the valve assembly **20**. The inclined flaps **55**, **65** of the valve gasket **50** provide soft contact surfaces **58**, **68** for preventing metal-to-metal contact with the reeds **33**, **34** during repeated flexing of the reeds **33**, **34**. This soft contact increases the durability of the reeds **33**, **34** and prevents the generation of NVH that could be experienced within the passenger compartment of the vehicle. The inclined configuration of the flaps **55**, **65** also prescribed the degree of flex experienced by each of the reeds **33**, **34**, which further improves the durability of the reeds **33**, **34** at the respective pivot portions **38**, **42** thereof. The progressively decreasing flow area through each of the flows paths formed through the valve body **80** prevents an undesired pressure drop or flow loss for the refrigerant when flowing towards the respective injection ports **17**, **18**.

Referring now to FIGS. **8-12**, a valve assembly **220** according to another embodiment of the present invention is disclosed. The valve assembly **220** is similar to the valve assembly **20** is many respects, and includes an injection plate **222**, a double reed structure **230**, and valve body **280**, each of which may be formed from the same materials described as being suitable for use in forming the corresponding components of the valve assembly **20**. The components forming the valve assembly **220** include similarly positioned locating openings and fastener openings for positioning the valve assembly **220** between the fixed scroll **5** and the rear housing **110** as described with reference to the valve assembly **20**, hence further description of these features and a method of assembly of the valve assembly **220** are omitted herefrom. However, the valve assembly **220** differs from the valve assembly **20** in that a valve gasket (not shown) of the valve assembly **220** is used only to form a peripheral seal between the injection plate **222** and the valve body **280** for preventing the lateral escape of the refrigerant passing through the valve assembly **220**, and is not disposed between the double reed structure **230** and the valve body **280** for providing a contact surface for the double reed structure **230** to engage during a flexing thereof as described hereinabove.

The injection plate **222** includes a substantially planar first major surface **223** and an oppositely arranged and also substantially planar second major surface **224**. The injection plate **222** includes a first injection hole **225** and a spaced apart second injection hole **226** extending through the injection plate **222** with respect to the axial direction from the first major surface **223** to the second major surface **224** thereof, wherein each of the injections holes **225**, **226** is positioned and shaped in similar fashion to the injections holes **25**, **26** of the valve assembly **20**.

The double reed structure **230** is a thin and planar plate-like body including a first major surface **231** and an oppositely arranged second major surface **232**. The double reed structure **230** includes a first reed **233**, a second reed **234**, and a connecting portion **235**, with the reeds **233**, **234** and the connecting portion **235** once again integrally formed as one monolithic structure. The first reed **233** includes an arm **237** extending longitudinally between a pivot portion **238** and an end portion **239** while the second reed **234** includes an arm **241** extending longitudinally between a pivot portion **242** and an end portion **243**. The reeds **233**, **234** once again pivot about the corresponding pivot portions **238**, **242** with the corresponding end portions **239**, **243** configured to selectively cover each of the corresponding injection holes **225**, **226**. The arms **237**, **241** and the end portions **239**, **243** include substantially similar shapes and configurations as the arms **37**, **41** and the end portions **39**, **43** of the double reed structure **30** of the valve assembly **20**. The connecting portion **235** differs from the connecting portion **35** of the valve assembly **20** in that the connecting portion **235** extends around a periphery of the double reed structure **230** when connecting the pivot portions **238**, **242** rather than extending across a central portion of the double reed structure **230**.

The valve body **280** includes a first major surface **281** thereof configured to engage the connecting portion **235** of the double reed structure **230** and an oppositely arranged second major surface **282** configured to face towards the outer face **16** of the fixed scroll **5**. The first major surface **81** includes a first indentation **285** corresponding to the first reed **233** and a spaced apart second indentation **295** corresponding to the second reed **234**. The first indentation **285** is defined by a surface **286** inclined at an angle relative to the plane of the periphery of the first major surface **281** with an axial depth of the first indentation **285** increasing as the surface **286** progresses towards the end portion **239** of the first reed **233**. The second indentation **295** is defined by a surface **296** inclined at an angle relative to the plane of the periphery of the first major surface **281** with an axial depth of the second indentation **295** increasing as the surface **296** progresses towards the end portion **243** of the second reed **234**.

The second major surface **282** of the valve body **280** includes a first post **283** projecting axially therefrom and towards the fixed scroll **5**. A first flow passageway **292** is formed through the valve body **280** and extends from a deep end of the first indentation **285** to an axial end of the first post **283** engaging the fixed scroll **5** around a periphery of the first injection port **17**. The first flow passageway **292** is formed from a first segment **293** extending from the surface **286** of the first indentation **285** and a second segment **294** extending to the end of the first post **283**. The first segment **293** includes a first diameter that is greater than a second diameter of the second segment **294**, thus the first segment **293** includes a greater cross-sectional flow area than the second segment **294**. The first segment **293** and the second segment **294** may be disposed at an angle relative to each other. In the illustrated embodiment, the first segment **293** is inclined relative to the axial direction of the valve assembly **220** while the second segment **294** is axially aligned with the first injection port **17** and arranged parallel to the axial direction of the valve assembly **220**.

The second major surface **282** of the valve body **280** includes a second post **284** projecting axially therefrom and towards the fixed scroll **5**. A second flow passageway **302** is formed through the valve body **280** and extends from a deep end of the second indentation **295** to an axial end of the second post **284** engaging the fixed scroll **5** around a periphery of the second injection port **18**. The second flow passageway **302** is formed from a first segment **303** extending from the surface **296** of the second indentation **295** and a second segment **304** extending to the end of the second post **284**. The first segment **303** includes a first diameter that is greater than a second diameter of the second segment **304**, thus the first segment **303** includes a greater cross-sectional flow area than the second segment **304**. In contrast to the first flow passageway **292**, the second flow passageway **302** includes the first segment **303** and the second segment **304** arranged in parallel and axially aligned with the second injection port **18**.

The first major surface **281** of the valve body **280** includes a peripherally disposed gasket groove **290** formed therein configured to receive a gasket therein. As mentioned above, the gasket disposed between the valve body **280** and the injection plate **222** does not extend to a position for interacting with the operation of the double reed structure **230**. Instead, the double reed structure **230** is sandwiched between the planar portions of the first major surface **281** and the second major surface **224** of the injection plate **222**.

The valve assembly **220** operates in substantially the same manner as the valve assembly **20**. The reeds **233**, **234** normally engage the injection plate **222** at positions covering the corresponding injection holes **225**, **226** until a pressure originating from the injection chamber **113** overcomes a pressure present in the respective injection ports **17**, **18** as well as the spring force formed by each of the reeds **233**, **234**. The force imbalance causes each of the reeds **233**, **234** to selectively flex away from the injection plate **222** to allow for fluid communication to occur between the injection chamber **113** and each of the respective indentations **285**, **295**. Each of the reeds **233**, **234** flexes towards the respective surfaces **286**, **296** defining the respective indentations **285**, **295** and refrigerant flows through the respective injection holes **225**, **226**, the respective indentations **285**, **295**, and the respective flow passageways **292**, **302** to provide fluid communication between the injection chamber **113** and each of the respective injection ports **17**, **18**.

From the foregoing description, one ordinarily skilled in the art can easily ascertain the essential characteristics of this invention and, without departing from the spirit and scope thereof, can make various changes and modifications to the invention to adapt it to various usages and conditions.

What is claimed is:

1. A valve assembly for a scroll compressor including a fixed scroll having a first injection port and a second injection port fluidly coupled to a compression mechanism of the scroll compressor, the valve assembly comprising:

a valve body having a first flow path and a second flow path formed therethrough, the first flow path fluidly coupled to the first injection port and the second flow path fluidly coupled to the second injection port;

an injection plate having a first injection hole and a second injection hole formed therethrough; and

a reed structure disposed between the injection plate and the valve body, the reed structure including a first reed configured to selectively permit a fluid to flow through the first injection hole towards the first flow path for entry into the compression mechanism through the first injection port and a second reed configured to selectively permit the fluid to flow through the second injection hole towards the second flow path for entry into the compression mechanism through the second injection port, wherein the first flow path is formed independently of the second flow path.

2. The valve assembly of claim **1**, wherein the first injection hole and the second injection hole are each fluidly coupled to an injection chamber formed in the scroll compressor.

3. The valve assembly of claim **1**, wherein the first reed and the second reed are arranged in a staggered configuration.

4. The valve assembly of claim **3**, wherein the first reed extends longitudinally in a first direction from a pivot portion thereof to an end portion thereof, and wherein the second reed extends longitudinally in a second direction from a pivot portion thereof to an end portion thereof, wherein the first direction is arranged opposite the second direction.

5. The valve assembly of claim **1**, wherein the reed structure includes a connecting portion connecting the first reed to the second reed, wherein the first reed, the second reed, and the connecting portion are formed as a unitary structure.

6. The valve assembly of claim **1**, further including a valve gasket disposed between the reed structure and the valve body, the valve gasket including a first flap configured to contact the first reed when the first reed selectively permits the fluid to flow through the first injection hole towards the first flow path.

7. The valve assembly of claim **6**, wherein the first reed is formed from a metallic material and the first flap is formed from an elastomeric material.

8. The valve assembly of claim **6**, wherein the first flap is inclined relative to a plane of the injection plate.

9. The valve assembly of claim **8**, wherein the first reed is configured to pivot away from the injection plate when the first reed selectively permits the fluid to flow through the first injection hole towards the first flow path, and wherein the first flap forms a stop surface for limiting the pivoting of the first reed away from the injection plate.

10. The valve assembly of claim **8**, wherein the first flap extends at least partially into the first flow path formed in the valve body.

11. The valve assembly of claim **6**, wherein a peripheral opening extends around at least a portion of a periphery of the first flap.

12. The valve assembly of claim **1**, wherein the first flow path formed through the valve body includes a first indentation indented into the valve body and a first flow passageway extending from the first indentation through the valve body.

13. The valve assembly of claim **12**, wherein the first reed pivots into the first indentation when the first reed selectively permits the fluid to flow through the first injection hole towards the first flow path.

14. The valve assembly of claim **12**, wherein the first flow passageway includes a first segment extending from the first indentation and a second segment extending from the first segment, the first segment having a first cross-sectional flow area and the second segment having a second cross-sectional flow area, wherein the first cross-sectional flow area is greater than the second cross-sectional flow area.

15. The valve assembly of claim **1**, wherein the first injection hole is elongated in a longitudinal direction of the first reed.

16. A valve assembly for a scroll compressor including a fixed scroll having a pair of injection ports fluidly coupled to a compression mechanism of the scroll compressor, the valve assembly comprising:

a valve body having a pair of flow paths formed therethrough, each of the flow paths fluidly coupled to a corresponding one of the injection ports;

an injection plate having a pair of injection holes formed therethrough;

a reed structure disposed between the injection plate and the valve body, the reed structure including a pair of reeds with each of the reeds configured to selectively provide fluid communication between a corresponding one of the injection holes and a corresponding one of the injection ports; and

a valve gasket disposed between the reed structure and the valve body, the valve gasket including a pair of flaps with each of the flaps configured to selectively contact a corresponding one of the reeds, wherein the pair of flow paths are formed independently of each other.

17. The valve assembly of claim **16**, wherein the valve assembly is divided into a first half and a second half, the first half having substantially identical structure to the second half.

18. The valve assembly of claim **17**, wherein the second half is rotated 180 degrees relative to the first half with respect to a central axis of the valve assembly.

19. A vapor injection scroll compressor comprising:

a compression mechanism formed by the cooperation of a fixed scroll and an orbiting scroll, the compression mechanism configured to compress a fluid therein, the fixed scroll including a pair of injection ports formed therethrough with each of the injection ports in fluid communication with the compression mechanism;

an injection chamber configured to receive a portion of the fluid after being compressed within the compression mechanism; and

a valve assembly including:

a valve body having a pair of flow paths formed therethrough, each of the flow paths fluidly coupled to a corresponding one of the injection ports;

an injection plate having a pair of injection holes formed therethrough; and

a reed structure disposed between the injection plate and the valve body, the reed structure having a pair of reeds, each of the reeds configured to selectively provide fluid communication between the injection chamber and a corresponding one of the injection ports, wherein the pair of flow paths are formed independently of each other.

* * * * *